MATEC Web of Conferences **67**, 05003 (2016) DOI: 10.1051/matecconf/20166705003
SMAE 2016

The Finite Element Analysis of the Strain Release Coefficients of the Q345b Steel

Zhuangnan ZHANG[1,a], Lu TIAN[1,b] and Yuanzhi WANG[1,c]

[1]Shenyang Jianzhu University, Shenyang, Liaoning China

[a]zhuangnanzh@163.com

[b]82785677@qq.com

[c]243513830@qq.com

Abstract. In order to investigate a simpler and easier method to determine the strain release factors *A* and *B* during the measurement of residual stresses by the blind-hole method. According to the basic principle of blind-hole method and the test results, three-dimensional model was created to simulate *A*, *B* value, and the materials used in measuring welding residual stresses is steel Q345b. After analyzing the finite element results, the variation formula was obtained which the strain release factors changing with energy parameter *S*. By analyzing the influences of the plate thickness (*T*) on the strain release factor *A*, *B* values, the results are shown that with the increase of the *T*, the value of *A* increases and *B* decreases.

1 Introduction

At present, blind hole method, which is included in the ASTM standard[1], is a highly effective method for measuring residual stresses. Stress releasing factors *A* and *B* play a great importance in the measuring accuracy of the blind-hole method. With the rapid development of computer technology, finite element simulation (FES) gradually to be the main way to measure the strain release factor. However, the FES of the strain release coefficients were worth further studying to make this method become more mature.

In this paper, the component properties used in the FES was got by the tensile test of Q345b steel. Firstly, according to the basic principles on the measuring residual stress when using the blind hole, calibrating the strain release factor *A*, *B* value. And, the FES results were compared with the test results. Then, coefficient *A*, *B* correction method based on specific energy *S* modification according to hole edge shape was used to eliminate that affect of hole edge plastic deformation. It can get the modified formula. Finally, by selecting different values of the plate thickness, for a detailed study of the different plate thickness of the strain release factor *A*, *B* values using the finite element method.

* Corresponding author:zhuangnanzh@163.com

2 The basic principle of blind-hole measurements

The blind-hole method to measure the welding residual stress and the strain release coefficients are carried on the detailed elaboration in literature [2], so, it will not introduced in careful in this paper.

During the uniaxial tension experiment, assuming σ_1=0,σ_2=σ, and get the formula (1) [2] :

$$\begin{cases} A = \dfrac{\varepsilon_1 + \varepsilon_3}{2\sigma} \\ B = \dfrac{\varepsilon_1 - \varepsilon_3}{2\sigma} \end{cases} \tag{1}$$

In the formula, ε_1, ε_2, ε_3 respectively means the strain value, and the unit is με; A, B are the strain release factors, the unit is με/MPa.

The ε_{10}, ε_{30} value before drilling hole and the ε_{11}, ε_{31} value after drilling the blind hole will be inserted into the type (2), then get the release strain values ε_1 and ε_3.

$$\begin{cases} \varepsilon_1 = \varepsilon_{11} - \varepsilon_{10} \\ \varepsilon_3 = \varepsilon_{31} - \varepsilon_{30} \end{cases} \tag{2}$$

After that, put the calculated values of ε_1, ε_3 inserted into the formula (1) to get the strain release factors A and B.

3 Test for the Values of A and B

During the calibration experiments, the specimen was used grade Q345b hot rolled steel plate, which made by the shenyang morigane component co. LTD. After tensile test, the mechanical properties of this batch were gained, just as shown in table 1.

The standards of ASTM E837-81 and E837-85 made clear that the stress application scope of the blind hole method to measure residual stress can not exceed half of the material yield strength [3]. Therefore, the stress applied range is 25MPa to 180MPa in the process of uniaxial tension test.

Table1 Mechanical Properties Of Q345b

T（mm）	yield strength（f_y）（MPa）	ultimate strength（f_u）(MPa)	modulus（E）（MPa）	poisson ration（v）	elongation ($\delta\%$)
14	358.7	464.8	207931	0.28327	29.94

Read measured results of ε_{10}, ε_{30}, ε_{11}, ε_{31}, and then put it into the formula (2) and (3) to gain the A, B values under the elastic state: A = -0.239με/MPa, B = -0.582με/MPa.

4 The Finite Element Results of A, B

Take a quarter of the specimens modeling, and the selection element is the entity elements SOLID95 of 20 nodes. The finite element model built as shown in fig.2. The model material uses the linear strengthening elastic-plastic material model, obeys the isotropic hardening, satisfies the Mises yield criterion. The boundary conditions in FES are: the displacement of all the nodes on the surface of yoz is zero along x direction; the displacement of all the nodes on the surface of xoy is zero along z direction; and for avoiding the mechanism singularity of the model, the displacement of the node (0,0,0) is zero along z direction.

5 Text and indenting

According to the data of the test and FES in literature [4] and NR method, finite element model was created to determine the blind-hole method strain release factors *A* and *B*. Then, put the results of FES to compared with the results of literature, the compared results are shown in table 2.

Through the data in table 2 shows that the deviation between the FES results and the literature results is about 5%. It indicated that the *A*, *B* value of the simulated results are very close to the literature results, both are in good agreement. So, using the finite element model, boundary conditions and constraints noticed in this paper to calibrate the strain release factor is feasible.

6 Simulation of the experiment

The finite element model size is 98 mm x 30 mm x 14 mm; Birth-death element method is used to open the blind hole, and the blind hole size are: aperture d = 1.5 mm and hole depth h = 2 mm; The distance from the measuring point to the hole heart is 3mm.

Table2 The Contrast Of The Literature Results And The Simulation Results

The results of literature		The results of FES		$\lvert (A_2-A_1)/A_1 \rvert$	$\lvert (B_2-B_1)/B_1 \rvert$
A_1	B_1	A_2	B_2		
-0.3706	-0.7709	-0.3669	-0.7633	0.99%	0.98%
-0.3705	-0.7707	-0.3669	-0.7631	0.97%	0.98%
-0.3704	-0.7705	-0.3667	-0.7629	0.99%	0.98%
-0.3704	-0.7703	-0.3667	-0.7628	0.99%	0.97%
-0.3703	-0.7702	-0.3642	-0.7602	1.64%	1.29%
-0.3702	-0.7700	-0.3665	-0.7624	0.99%	0.98%
-0.3706	-0.7726	-0.3675	-0.7677	0.83%	0.63%
-0.3730	-0.7832	-0.3701	-0.7792	0.77%	0.51%
-0.3774	-0.7998	-0.3745	-0.7955	0.76%	0.53%
-0.3831	-0.8230	-0.3796	-0.8181	0.91%	0.59%
-0.3863	-0.8601	-0.3836	-0.8547	0.69%	0.62%
-0.3852	-0.9161	-0.3843	-0.9067	0.23%	1.02%
-0.3976	-0.9909	-0.413	-0.9818	3.87%	0.91%

7 Instruction and analysis of the elastic results

During the process of tensioning, the loading mode is the displacement load, and the corresponding load range from 25MPa to 180MPa. The simulation results are shown in table 3:

Table3 The Results Of The Fea

d(mm)	ε_1 ($\times10^{-6}$)	ε_3 ($\times10^{-6}$)	A ($\times10^{-6}$/MPa)	B ($\times10^{-6}$/Mpa)
0.011783	-19.35	7.415	-0.2387	-0.5353
0.023566	-38.69	14.828	-0.2386	-0.5352
0.035348	-58.03	22.24	-0.2386	-0.5351
0.047131	-77.35	29.64	-0.2386	-0.5350

where d is defined as the applied displacement.

Take the average of the finite element results as the calibration result: A=-0.2386με/MPa, B=-0.5350με/MPa.

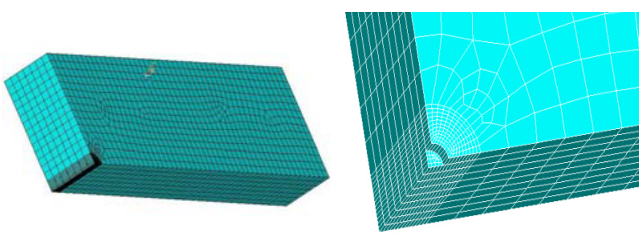
Table4 The Comparison Of The Simulation Results And The Test Results

simulated results (10^{-6}/MPa)		test results (10^{-6}/MPa)		$(A_f-A_e)/A_e$	$(B_f-B_e)/B_e$
A_f	B_f	A_e	B_e		
-0.2386	-0.5350	-0.239	-0.582	0.17%	8.0%

As shown in table 4, the A, B values of the FES calibration are very close to the results of the experimental. A value of error is less than 0.17%, B error of less than 8.0%. So, using the finite element simulation method to calibrate the strain release factor is feasible.

8 Instruction and analysis of the yield results.

When the load exceeds half of material yield strength, the residual stress in the weld and the vicinity region will be reached or exceeded the yield strength σ_s . If still used the elastic state method to calculate the residual stress, with the influences of the stress concentration caused by drilling and the plastic strain effect, the calculation results could be far greater than σ_s. In order to measure components' residual stress in the yield status, blind-hole releasing method must be amended to eliminate that affect of hole edge plastic deformation, which influences the measurement accuracy. By using coefficient A, B correction method based on specific energy S modification according to hole edge shape, the measurement accuracy of welding residual stress is improved and the measurement scale is improved. The relationship curves of parameter S and A, B as shown in figure 2.



(a) (b)

Fig.1 the finite element model

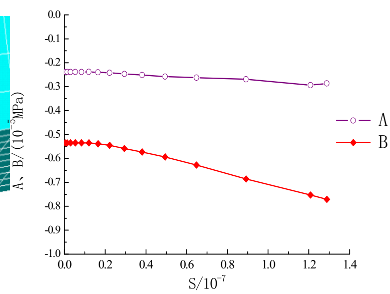


Fig.2 The coefficients change with S

As shown in figure 2: when $S \leq 0.165$, absolute value of A and B slightly changed as S increases; When $S > 0.165$, the hole begins to yield. At this points, linear regression analysis to the release coefficient and S, just as shown in fig.2. It can get the modified formula (3) when the hole edge occurs the plastic deformation.

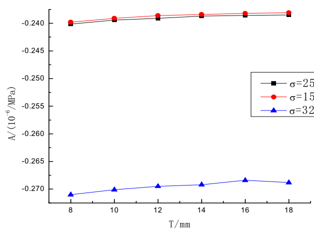
$$\begin{cases} A' = -0.0443\,S - 0.2337 \\ B' = -0.2148\,S - 0.4927 \end{cases}, \quad S > 0.165 \tag{3}$$

9 The Influences of the Thickness to A, B

A lot of experiment and research shows that as the change of thickness T, A, B value will change [5]. By selecting different values of the plate thickness, for a detailed study of the different plate thickness of the strain release factor A, B values using the finite element method. Take the plate thickness T is 8 mm, 10 mm, 12 mm, 14 mm, 16 mm, 18 mm for measuring the A, B values in load of σ=25MPa,σ=150MPa,σ=325MPa respectively. The simulated results are shown in table 5, the changes of T and A, B as shown in figure 3, figure 4.

 DOI: 10.1051/matecconf/20166705003

Through analysis from fig.4 and table.5 we can see: factor A increases as plate thickness increases while factor B obey the opposite trend, no matter what they're in elastic states or yield status.



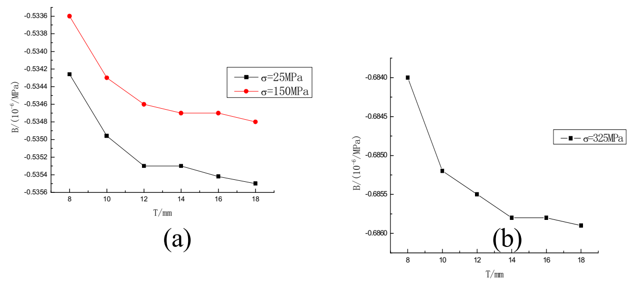


Fig.3 coefficient A change with thickness　　Fig.4 coefficient B change with thickness

Table5　The Coefficients A, B Change With The Thickness

T(mm)	σ=25MPa		σ=150MPa		σ=325MPa	
	A_{25}	B_{25}	A_{150}	B_{150}	A_{325}	B_{325}
8	0.24014	0.53426	0.2398	0.5336	-0.271	-0.684
10	0.23944	0.53496	0.2391	0.5343	-0.2701	-0.6852
12	-0.2391	-0.5353	-0.2386	-0.5346	-0.2695	-0.6855
14	-0.2387	-0.5353	-0.2384	-0.5347	-0.2692	-0.6858
16	-0.23858	-0.53542	-0.2382	-0.5347	-0.2684	-0.6858
18	-0.2385	-0.5355	-0.2381	-0.5348	-0.2688	-0.6859

10 Conclusions

(1) when the applied load doesn't reach 1/2σs, the A,B value of the FEM calibration are very close to the results of experimental. So, using the finite element simulation method to calculate the strain release factor is feasible;

(2) when $S \leq 0.165$, the strain release factors is almost a constant; when $S > 0.165$, the hole begins to yield. And, linear relationship between the release coefficient and S is excellent. According to the plastic correction formula, which gained in this paper, the A, B values in the yield status can get a ideal modify effect;

(3) A increases as plate thickness increases and B decreases.

11 Acknowledgements

This work described in this paper was supported by National Science Found of China (51108279), their supports are gratefully acknowledged.

References

1. ASTM Standard E837,Standard test method for determining residual stresses by the hole-drilling strain gage method[S]
2. Hou Hailiang,Zhu Xi,Liu Runquan.2003.FEM analysis on the strain release factors for measuring welding residual stresses using blind-hole method[J].Journal of Mechanical Strength,25(6):632-636
3. Mathar J.1934.Determination of initial stresses by measuring the deformations around drilled
4. Liu Xiaohong.2010.numerical simulation of the blind-hole measures strain release factor of residual stress under the yield status[D].Guangxi University.
5. Feng Wenjian.2012.Finite element method analysis of the strain release factors for measuring residual stresses in steel structure by blind-hole method[J].Fujian Architecture & Constructure165(3):52-54