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Residual Stress Measurement of Aluminum 5052 Using X-Ray Diffraction Method

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Abstract— **X-ray diffraction method measures the strains closer to the surface. It has the ability to measure the strain or the changes in strain, from an unstressed state, by measuring the shifts in the diffraction peak due to a residual stress. Today the aluminum alloys contribution is increasing in manufacturing the aerospace components with good forming nature and high strength. During the forming of a component, stresses are developed and retains with the material. This metal alloy should posses' sufficient strength to bear the strains developed during flight as the development of strains extinct decides component of life.**

In the present work, A5052 is selected to analyze the forming nature under grease and annealed conditions using Erichsen cupping test method. Finally the residual stresses of A5052 are also analyzed for two conditions to know the residual stress left over in the material after cupping test. Therefore the effect of stresses is analyzed in a formed component to decide the aerospace component life.

***Index Terms*—About four key words or phrases in alphabetical order, separated by commas.**

I. INTRODUCTION

Residual stresses develop during the manufacturing processes involving material deformation, heat treatment or processing operations that transform the shape or change the material properties. The residual stresses could be large to cause local yielding and plastic deformation, both on a microscopic and macroscopic level and can severely affect component performance. Therefore it is important that knowledge of the internal stress state can be deduced either from measurements or modeling predictions.

II. METHODOLOGY

A. Erichsen Cupping method:

The method is used to assess the stretch formability of sheets. This is carried out on an erichsen cupping machine equipped 'with a die, punch and blank holder with dimensions and tolerances.

This method consists of forming an indentation by pressing a punch with a spherical end against a test piece clamped between a blank holder and a die, until a through crack appears and the depth of cup is measured.

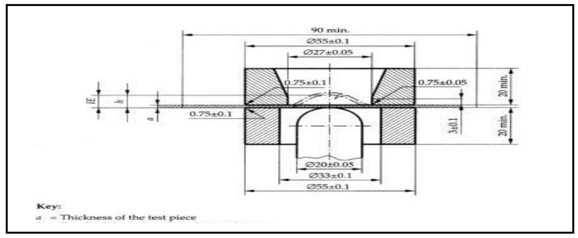

Fig. 1. Erichsen cupping method

The standardized dimensions of the test set-up are shown in the figure below. The ball punch is forced onto the sheet specimen till cracks begin to appear in the bulge dome. The distance the punch travel is referred to as the Erichsen drawing index IE and is defined as a measure for the formability of the sheet during stretch forming.

B. HEAT TREATMENT

In order to test the material for formability under annealed condition, Annealing is carried out in an electric resistance furnace. The test pieces are annealed by heating at temperature of 340 °C and soaking them at this temperature for 1 hour and then furnace cooled.

III. X-RAY DIFFRACTION METHOD

X-ray diffraction is one of the standard methods for measuring the residual stress .It measures the strain by measuring the shifts in the diffraction peak due to an external or residual stress. The measured strains are then converted into a stress. These calculations assume a linear elastic deformation of the material. The residual stresses determined by using x-ray diffraction assume an arithmetic average of the stress in the volume of the material. This volume is based on the depth of penetration of the x-ray beam, which is governed by the linear absorption coefficient of the material based on the type of radiation used.

For aluminum alloys, 70% of the diffracted radiation comes from the top 100 microns of the material when used laboratory x-ray sources. Because of this shallow depth of penetration, the spatial resolution of the residual stresses will be approximately 10 to 100 times more than other stress. The

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depth of penetration is dependent on the type of radiation. Cu-Kα radiation, Co- Kα radiation and Cr-Kα radiation are some of the common types of radiation used in laboratory settings. The limited selection of laboratory x-ray tubes leads to a limited choice of crystallographic planes that can be used for the residual strain measurement.

The XRD equipment used in this work is a Proto Manufacturing Laboratory Non-Destructive Residual Stress Measurement System. It has a MG2000L goniometer that rotates the XRD goniometer in the ψ -direction. A separate mounting table rotates the specimen in the ψ -direction and can automatically move the specimen. The analysis software, XRDWin 2.0, is a windows based package that has the capability to analysis and display d vs. sin2 ψ using a wide variety of curve fitting models for the peak profile analysis.

A. Specimen Set-up and Orientation:

The formed annealed specimen of A5052 is mounted on a metal block of the equipment. This mounting arrangement is used to achieve a stable placement in the XRD. The formed annealed sample is placed in longitudinal direction to perform the residual stress test.

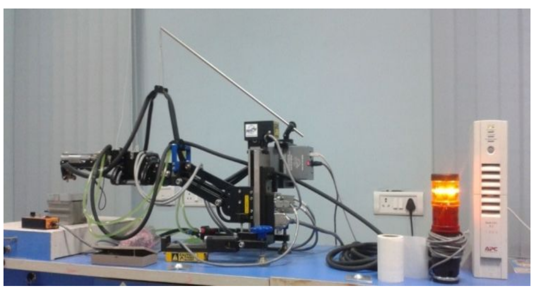


Fig. 2. X-ray Diffraction Equipment

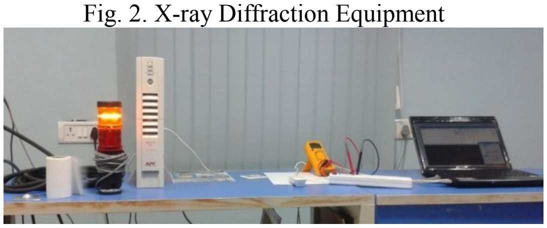


Fig. 3. XRD equipment with XRD win 2.0 software

B. X-ray Tube Selection:

The choice of the type of x-ray radiation to use is a balance between depth of penetration and availability of a sufficiently strong diffraction peak within the appropriate angular range for the x-ray diffractometer. The present work exclusively used the copper tube with Cu-Ka radiation for all measurements.

C. ψ Angle Selection:

Angles of ψ were chosen to give a symmetric and wide range of sin2 ψ values when viewed on d vs. sin2 ψ plot. The x-ray diffractometer used single-exposure technique at multiple ψ -tilts with two position sensitive detectors. Cu-Ka radiation has a wavelength of 1.542nm and using the {422} reflection of aluminum, which is faced-centered cubic, the lattice parameter and the Miller indices of h=4, k=2, and l=2 .The XRD Win 2.0 software needed a minimum of eleven ψ angles per each position detector in order to calculate the stresses at a given location

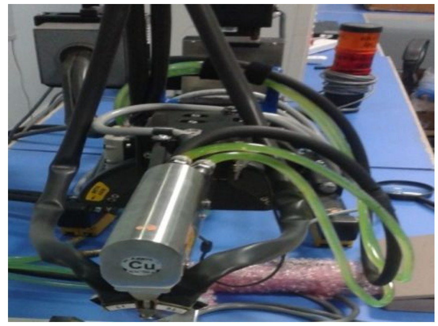


Fig. 4. Cu-Ka tube for testing

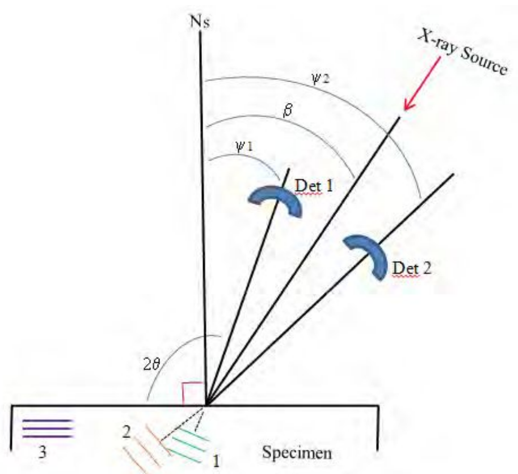


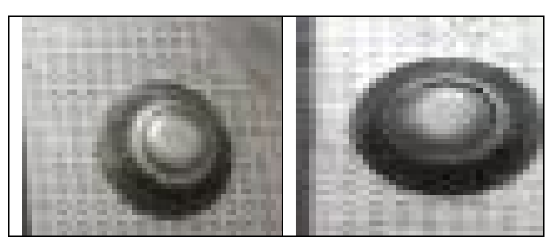
Fig. 5. Specimen and detector

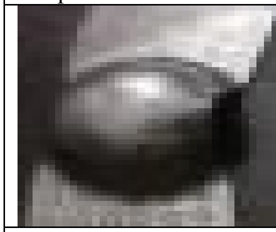
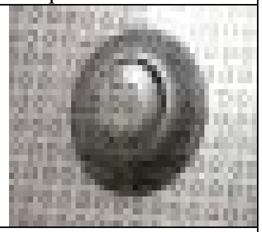
IV. EXPERIMENTAL WORK

In the present work, A5052-H32 alloys is selected for formability analysis using Erichsen cupping test on an erichsen cupping machine to analyze the material. Further the residual stresses have been analyzed under grease and annealed conditions. The sample sizes of lubricant condition and heat treated conditions are shown in the table below. These samples are further analyzed for formability and the formed samples are shown below.

TABLE 1.SAMPLE SIZES

ALLOY	LUBRICANT CONDITION SAMPLES	ANNEALED CONDITION SAMLES
5052	70*70*1.8mm 70*50*1.8mm 70*30*1.8mm	70*70*1.8mm 70*50*1.8mm 70*30*1.8mm



Formed Lubricant sample of 70*70mm	Formed Lubricant sample of 70*50mm
	
Formed Lubricant sample of 70*30mm	Formed Annealed sample of 70*70mm

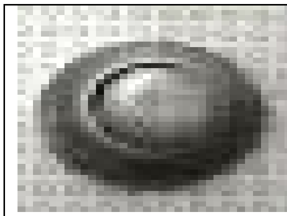
	
Formed Annealed sample of 70*50mm	formed Annealed sample of 70*30 mm

Fig. 6. Formed Samples of A5052

A. ERICHSEN INDEX VALUES OF A5052 GREASE AND ANNEALED SAMPLES:

The erichsen index values are noted for both grease and annealed conditions.

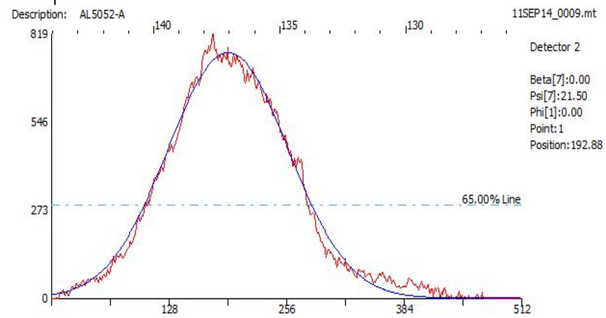
Sample size	Lubricant Samples	Annealed Samples
1	10.39	10.53
2	10.69	12.54
3	15	16.52

B. RESIDUAL STRESS MEASUREMENT OF A5052 ANNEALED AND LUBRICANT SAMPLES:

Fig. 7. XRD testing sample

For the A5052 formed annealed sample, 13 ψ angles are recorded and a continuous peak is attained. The residual stress is measured using the distance between crystallographic planes which is d-spacing, as a strain gage and ψ angle. As 2 detectors are used, the readings of d spacing and $\sin^2\psi$ are shown in detector 1 and detector 2 in the below table. Therefore the residual stress for the annealed sample is obtained.

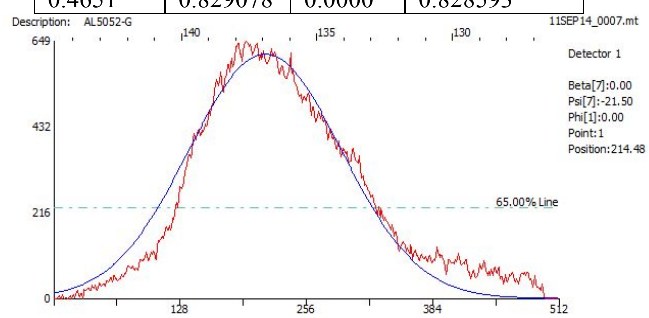
The same procedure is repeated for the residual stress testing of grease sample.13 ψ angles and d spacing are recorded .The continuous peak and the data of d spacing and $\sin^2\psi$ are shown below.



Graph. 1. Peak distribution of annealed XRD sample

TABLE II. D SPACING AND SIN^2PSI VALUES OF ANNEALED SAMPLE:

DETECTOR 1		DETECTOR 2	
Sin^2psi	DSpacing	Sin^2psi	DSpacing
0.0000	0.828941	0.4651	0.829432
0.0101	0.828682	0.3659	0.828554
0.0316	0.828489	0.2927	0.827954
0.0675	0.828515	0.2195	0.827927
0.0732	0.828474	0.2104	0.827977
0.1227	0.828627	0.1464	0.828439
0.1343	0.828674	0.1343	0.828456
0.1464	0.828461	0.1227	0.828711
0.2104	0.828901	0.0732	0.828752
0.2195	0.829007	0.0675	0.828756
0.2927	0.829061	0.0316	0.828814
0.3659	0.828923	0.0101	0.828950
0.4651	0.829078	0.0000	0.828593



Graph. 2. Peak distribution of grease sample

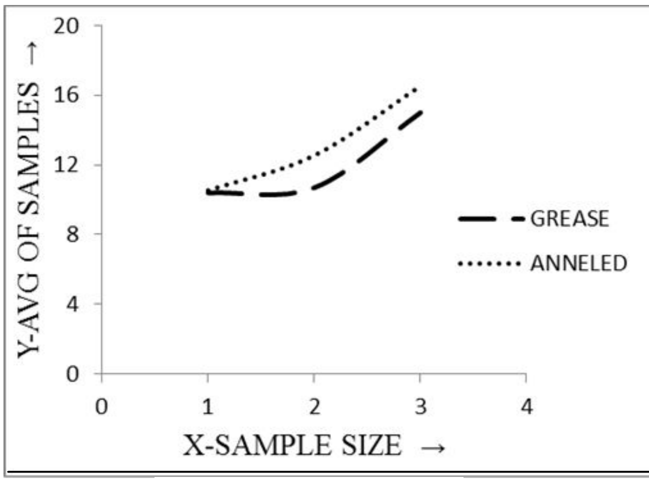
TABLE. III. D SPACING AND SIN^2PSI VALUES OF GREASED SAMPLE:

DETECTOR 1		DETECTOR 2	
Sin^2psi	DSpacing	Sin^2psi	DSpacing
0.0000	0.827897	0.4651	0.828131
0.0101	0.828681	0.3659	0.828651
0.0317	0.829246	0.2927	0.828744
0.0675	0.829155	0.2195	0.828761
0.0731	0.829059	0.2105	0.828665
0.1228	0.828833	0.1463	0.828370
0.1343	0.828853	0.1343	0.828275
0.1463	0.828718	0.1228	0.828205
0.2105	0.829123	0.0731	0.828117
0.2195	0.829107	0.0675	0.828128

0.2927	0.829457	0.0317	0.828636
0.3659	0.829806	0.0101	0.828996
0.4651	0.830038	0.0000	0.828914

V. RESULTS:

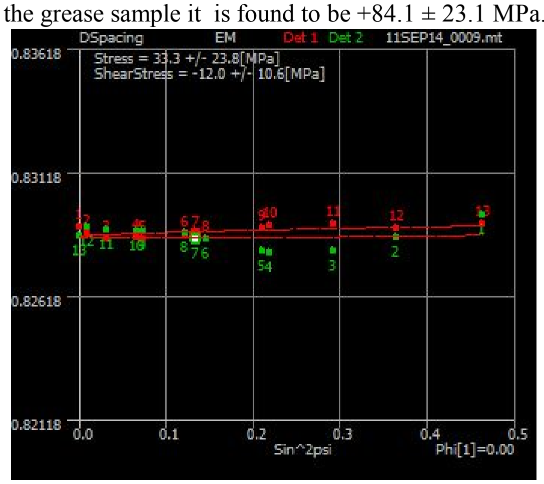
The formability of A5052-H32 samples were carried out using erichsen cupping test. The test on the samples is carried out until the necking of fracture and the cup height is measured. The comparison graph of both grease and annealed condition is plotted between the sample sizes on the x-axis and the erichsen index on the y-axis. From the graph it is observed the annealed sample is having more E.I in comparison to other conditions to grease sample. Therefore, as the height is high, the formability of the material is high and the material can be formed easily. This can be attributed to the less residual stress developed in the material during forming.



Graph. 3 erichsen index values

A. RESIDUAL STRESS MEASUREMENT:

The residual stress test is conducted for formed annealed and grease samples and the results are compared .A plot of d spacing on y-axis and sin2ψ on x-axis for annealed and grease samples are shown. The residual stress obtained for the annealed sample is found to be +33.3 ± 23.8 MPa and for the grease sample it is found to be +84.1 ± 23.1 MPa.



Graph. 4 d spacing versus sin2ψ values of annealed sample

Graph. 5 d spacing versus sin2ψ values of grease samples

VI. CONCLUSION

The formability of A5052-H32 sheets are conducted using erichsen cupping method at lubricant condition and annealed condition to improve the forming nature. The erichsen cup index of A5052 samples is examined and therefore the annealing samples showed enhanced good formability compared to other condition.

The residual stress for the A5052 samples of grease condition and annealed condition are carried out on XRD data using d vs. sin 2psi technique. The results showed that A5052 annealed sample is having less residual stress compared to A5052 grease sample.Therfore the less residual stresses examined in the annealed sample is a good validation to the high erichsen index obtained in annealed sample. As residual stresses are less in A5052 annealed component, the components formed with annealed condition will provide better services during operating conditions.

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REFERENCES

[1] N. S. Rossinia, M. Dassistia, K. Y. Benyounisb and A. G. Olabib," Methods of Measuring Residual Stresses in Components ", SEM, Bethel 2005.

[2]M.R. Hill," Determination of residual stress based on the estimation of Eigen strain", USA: Stanford University; 1996.

[3]A.T. DeWald, "Measurement and modeling of laser penning residual stresses in geometrically complex specimens", USA: University of California; 2005.

[4]M.E. Kartal, C.D.M. Liljedahl, S. Gungor, L. Edwards, M.E. Fitzpatrick," Determination of profile of the complete residual stress tensor in a VPPA weld using the multi-axial contour Method", Acta Materialia 2008; 56: 4417–4428.

[5]R. Gunnert,"Method for measuring residual stresses and its application to a study of residual Welding stresses", Stockholm: Almqvist & Wiksell 1955.

[6]J. Schwaighofer," Determination of residual stresses on the surface of structural parts", Experimental Mechanics 1964; 4(2): 54–56.
[7]By Brian j. Banazwski,"Using x-ray diffraction to assess residual stresses in laser peened and welded aluminum" December 2011
[8]www.protomanufacturing, automated residual stress analysis.com.