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Experimental and Computer Aided Analysis for the Reduction of Damage in Sheet Metal Forming

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Abstract- This paper gives knowledge about the behavior of cold rolled steel IS 513_2008 CR2_D having grade D for the reduction of ductile damage. CR specifies Cold Rolled and D for drawing grade. Problems encountered during sheet metal forming operations are dent, wrinkles, thinning, and spring back, insufficient stretching etc. In this paper wrinkle defect was studied experimentally and by using FE software.

Keywords- Wrinkling, Friction, Deep drawing, FE software-LS DYNA

I. INTRODUCTION

Sheet metal forming processes comprises several processes classified as cutting processes and plastic deformation processes. Deep drawing comes under plastic deformation process in which metal blank is shaped into the cavity provided in die due to the force provided by punch.

Different types of defects occurring are as follows rupture, insufficient stretching, thinning etc. and particularly in deep draw metal forming operations are wrinkling, tearing, cracks, thinning etc. Deep drawing is a process in which raw material i.e. blank is shaped into the cavity provided in the die. Mainly manual, mechanical, hydraulic and pneumatic presses are used for the deep draw operation. Yoshida et al. have conducted a series of work on wrinkle suppression [1]. For the wrinkling analysis purpose hydraulic press of capacity 250 ton was used. The reason of wrinkles at the corner area was studied by Lee et al [2].

In this paper the wrinkle analysis of auto component is done. The component formed was found with wrinkles, cracks several times. After literature survey it was found that wrinkles and cracks can be eliminated to large extent. Several parameters which majorly contribute for wrinkle formation such as blank holding pressure, nose radius, geometry, draw depth, anisotropic properties of material, die design and shape of work piece, contact conditions etc. It is difficult to analyze wrinkling initiation and growth while considering all the factors because the effects of the factors are very complex and studies of wrinkling behavior may lead to a wide scattering of data even for small deviations in factors. In the present study, the mechanism of wrinkling initiation and crack growth in the cylindrical cup deep drawing process was studied. The work was carried out by doing experimentation on single stage hydraulic machine and the results were confirmed with LS-DYNA software.

Wrinkling is not desirable as while doing the assembly of the part using welding or any other joining operation the strength found to be very weak and it destroy the appearance of the component. Wrinkling mostly occur due to excessive compressive force acting on the sheet metal. High frequency wrinkles can damage the die in case of multistage operations.

II. CHEMICAL COMPOSITION OF MATERIAL

The chemical composition of cold rolled steel tested on optical emission spectrometer.

Table 1: Chemical composition of material

C	Si	Mn	P	S	Cr	Ni	Al	Cu	Co	Ti	Nb	V	W
%	%	%	%	%	%	%	%	%	%	%	%	%	%
0.0425	0.0083	0.2292	0.004	0.002	0.0158	0.138	0.0465	0.0052	0.0062	0.001	0.003	0.001	0.001
B	**Sn**	**Zn**	**As**	**Bi**	**Ca**	**Ce**	**La**	**Fe**	**Mo**	**Pb**	**Zr**		
%	%	%	%	%	%	%	%	%	%	%	%		
0.0004	0.0025	0.002	0.002	0.002	0.0002	0.003	0.001	99.6	0.002	0.003	0.002		

III. ANISOTROPY PROPERTY OF COLD ROLLED STEEL

Anisotropic properties are the directional dependent properties means if rolling direction is changed there will be slight variation in mechanical properties. It can be calculated by uni-axial tension tests conducted in 0°, 45° and 90° with respect to rolling direction.

Plastic Strain Ratio (R_0) = $\dfrac{\mathrm{Ln}\left(\frac{\text{Width final}}{\text{Width initial}}\right)}{\mathrm{Ln}\left(\frac{\text{Thickness final}}{\text{Thickness initial}}\right)}$

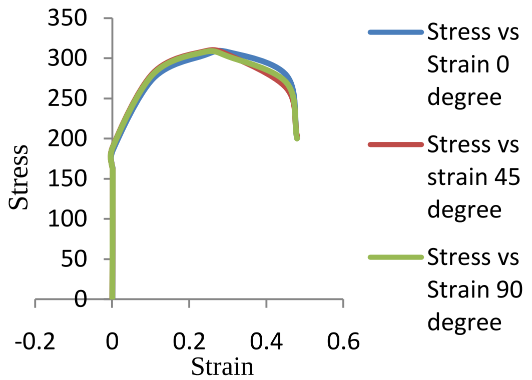

Fig 1: Stress strain cure observed in different rolling direction

The nature of stress strain curve in different rolling direction is shown in above curve. The behavior of stress strain curve in different rolling direction is almost same. Calculation of normal 'R' value is taken to be average 'r' value:

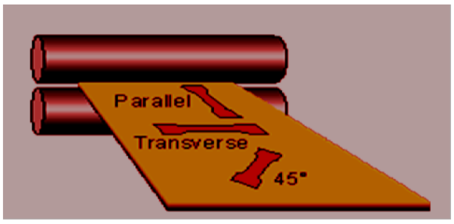

Fig2: Specimen with different rolling direction

Lankford coefficient (R) = $\dfrac{R_0 + 2R_{45} + R_{90}}{4}$

Normal R value of the material strongly depends on the strain.

Calculation of planar anisotropy coefficient value R_p

$$R_p = \frac{R_0 - 2R_{45} + R_{90}}{2}$$

For Isotropic material- The material has same property in all directions.
For Planar anisotropy- The R values vary at different directions to the rolling direction: R_0 not equal to R_{45} not equal to R_{90}. This can lead to 'earring' in deep drawing.
For Normal anisotropy- $R_0 = R_{45} = R_{90}$ but not equal to 1.
The value R determines the limiting drawing ratio, and R_p is in correlation with the extent of earring. A combination of high R and low R_p provides optimal drawability.
The results obtained after doing uni-axial tensile testing is tabulated follows:

Table 2. Material properties of cold rolled steel

Parameters	Yielding stress, σs (MPa)	Ultimate tensile stress, σ_{ut} (MPa)	Total elongation, δl (%)	Strain hardening exponent, n	Hardening coefficient, k (MPa)	R_0	R_{45}	R_{90}	$R_{avg.}$ Lankford Coefficient
Values	217.78	307.83	40	0.19	502.73	1.42	1.2	1.36	1.295

IV. EXPERIMENTATION

A) Experimental Setup

Hydraulic press of capacity 250Tons was used for final component as shown if figure 3. Deep drawing is a process in which final component is in cup shape and produced from Sheet metal. In this case single stage draw is done and finally inverted cup was obtained. The flange wrinkling was studied by J.Cao et al.[3].

Fig 3. Punch and die setup

Fig 4. Effect of varying Blank holding pressure & Draw depth

Fig 5. Location of cup in automobiles

A blank-holder used to prevent wrinkling as it applies sufficient pressure on the blank studied in [4]. Hence, when drawing cups at larger draw ratios, larger radial tension are created on the flange and higher tensile stress is needed on the cup wall. Figure 4 shows the component obtained after varying parameters draw depth and blank holding pressure.
The wrinkling of stamping of a motor cycle oil tank was studied by Liao et al. Figure 5 shows the actual location of cup in automobile.

B) Observation Table

The observations were taken by varying the parameters such as blank holding pressure and draw depth. The optimum values were obtained at blank holding pressure 60kg/cm^2 and draw depth 29mm can be seen from table 3.

Table 3: Effect of varying Blank holding pressure & Draw depth

Sr. No.	Punch force (Kg/cm^2)	Blank Holding Pressure (Kg/cm^2)	Major Wrinkle Waves	Punch Speed (mm/sec)	Draw depth (mm)	Conclusion
1	100	30	17	8.6	26	Large wave count
2	100	35	15	8.6	26	Decreased wave count
3	100	40	12	8.6	26	Decreased wave count
4	100	45	4	8.6	26	Decreased wave count
5	100	60	Absent	8.6	26	Negligible waviness
6	100	65	Crack	9.3	24	Thinning & Crack
7	100	60	Absent	7.5	30	Waviness visible
8	100	60	Absent	7.9	29	No wrinkles

C) Effect of Various Friction Materials

There were different friction material used as a lubricant as shown in Table 4, 5 and 6. The most effective result was obtained by using Plastic paper and palm oil. There was one drawback that after using palm oil as a lubricant, cup formed was to be clean after forming.

Fig 6: Use of plastic paper as a lubricant

Table 4: Effect of Plastic paper 100micron-0.1mm as a friction material

Sr. No.	Punch force	Blank holding pressure	Punch Speed	Draw depth	Conclusion
1	100	50	7.7	29	Less wave count
2	100	55	7.7	29	Decreased wave count
3	100	60	7.7	29	No wrinkles
4	100	65	9.7	23	Wrinkles observed

Table 5: Effect of Palm Oil as a friction material

Sr. No.	Punch force	Blank holding pressure	Punch Speed	Punch Stroke	Conclusion
1	100	50	9.7	23	Wrinkles observed
2	100	55	7.7	29	Less wave count
3	100	60	7.7	29	No wrinkles
4	100	65	7.7	29	Thinning

Table 6: Effect of Hydraulic oil grade 68 as a friction material

Sr.	Punch force	Blank holding pressure	Punch Speed	Punch Stroke	Conclusion

No.					
1	100	50	9.7	23	Wrinkles observed
2	100	55	9.7	23	Wrinkles observed
3	100	60	8.6	26	Minute waviness
4	100	60	7.5	30	Waviness visible

V. SIMULATION

A) Creation of Model

The numerical model of forming of deep drawing process was built up by using CATIA.

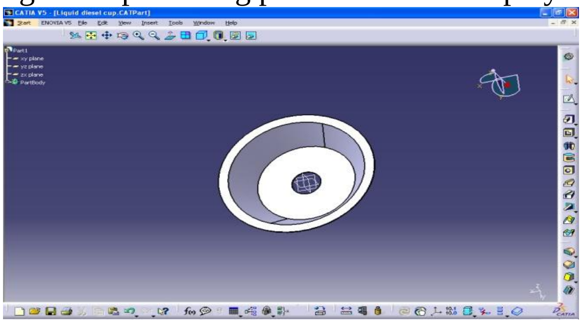

Fig 7: Component 3d model created in CATIA V5 R17

Above is the sample model created by using CATIA V5 R17 and then further it was analyzed using LS- DYNA software.

A) Analysis of Model

The numerical model was analyzed using LS DYNA software. All the observed values were analyzed for approaching toward the optimum value. It was observed that at blank holding pressure 60kg/cm^2 and the draw depth 30mm safe region was decreased and at for same blank holding pressure and 29mm increased safer region was observed.

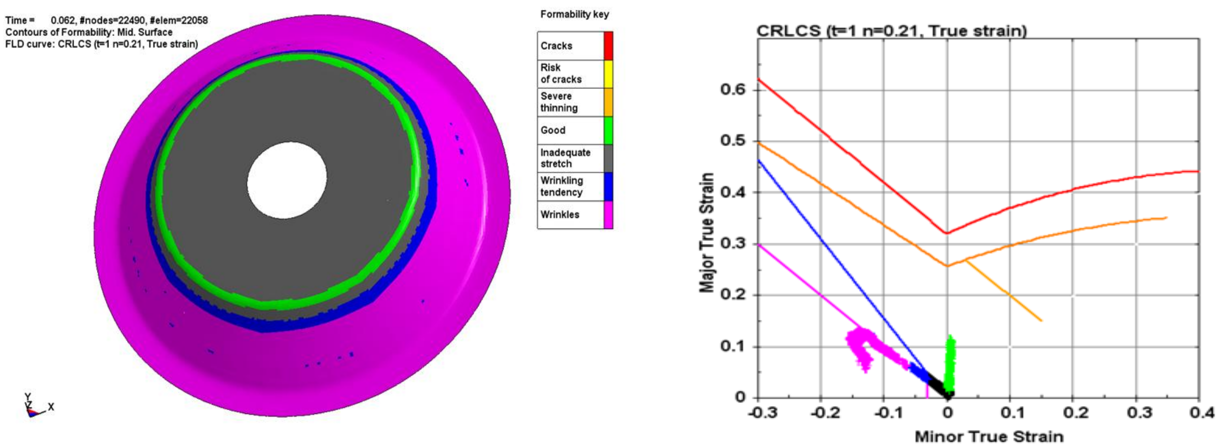

Fig 8: Component formability and FLD curve for Blank holding pressure 60kg/cm^2 and draw depth 30mm

Fig 9: Components formed using LS-DYNA

CONCLUSION

1. Wrinkle formation was decreased as blank holding pressure is increased which can be seen from table 3.
2. Decreased wave count was observed, if the draw depth is increased and also more compression region was formed which is highly undesirable.
3. Experimental and simulation results were found to be nearly same.

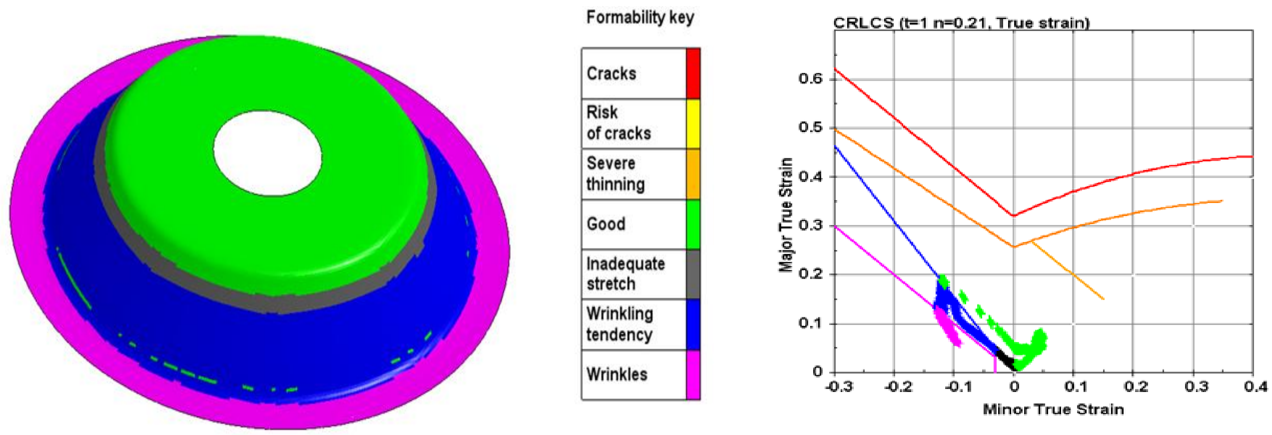

Fig 10: Component formability and FLD curve for Blank holding pressure 60kg/cm^2 and draw depth 29mm

1) The optimum value was observed at blank holding pressure 60 kg/cm^2 and draws depth 29mm as shown in Table 3, 4 and figure 8 and figure 10 shows optimum values.

2) The most effective result was obtained by using Plastic paper and palm oil as a lubricant.

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