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QUANTITATIVE APPLICATION OF TEXTURE DATA TO SHEET METAL FORMING

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INTRODUCTION

Controlling the texture of a sheet metal, which is evolved in manufacturing processes such as rolling or annealing, shall enable to produce a new type of sheet metal which has new properties as well as a better formability. To realize such developing of a high-grade sheet metal, it is necessary to make clear and to be predictable the quantitative relation between the texture and some properties as well as between the manufacturing process and the texture. In the present work, quantitative simulations of some macroscopic phenomena in a deep drawing process, such as strain distribution in a deformed sheet, earing in a drawn cup and predicting a blank contour for a non-ear cup, are tried based on its texture data.

THEORETICAL CALCULATION

Most macroscopic phenomena in a sheet forming process can be discussed on a basic property of stress-strain relation of the sheet. The stress-strain property under multiaxial stress states of an anisotropic sheet metal is calculated using its texture data based on following assumptions.[1]

(1) A textured polycrystalline sheet is simplified as an aggregate of many crystals with various orientations whose volume fraction are expressed by means of a crystallite orientation distribution function (CODF).

(2) Each crystal in the polycrystalline sheet is subjected uniformly to same stress state under loading.

(3) As a deformation mode, restricted glides on slip systems, 12 and 48 for a fcc and bcc metal, are considered.

(4) On the all slip systems a relation between a shear

stress τ and a shear strain γ is expressed by an equation,

$$\tau = k\ \gamma^{n} + \tau_{o} \tag{1}$$

where k, n and τ_o are constants.

Then strain components, ε_{ij} ;i,j=1,2,3, of the sheet subjected to any multiaxial stress state, σ_{ij} , can be calculated as follows.

$$\varepsilon_{ij} = (1/8\pi^2)\iiint \varepsilon'_{ij}(\phi,\theta,\phi)\cdot w(\phi,\theta,\phi)\sin\theta\ d\theta\ d\phi\ d\phi \tag{2}$$

$$\varepsilon'_{ij}(\phi,\theta,\phi) = \Sigma\, n_i^N b_j^N\ [(n_i^N b_j^N \sigma_{ij} - \tau_o)/k]^{1/n}$$

The n_i^N and b_j^N are direction cosines of a nomal of a slip plane and a slip direction in the slip system N. The ϕ,θ,ϕ are Euler angles which relates crystal axes to sheet reference axes and $w(\phi,\theta,\phi)$ is the CODF analized from texture data.

SOME APPLICATIONS IN DEEP DRAWING

Failure initiation

Stress states in a flange and a wall during cup drawing are shown in Figure 1. An initiation of a failure at a cup wall, which controls a drawing limit, is predictable by comparing the stresses σ_s and σ_w in the Figure 1. The fail ure occors in the fixed direction because of an anisotropy of the sheet.

Figure 2 shows equivalent stress-strain relations calculated from Eq.(2) and measured under two types of stress states shown in Fig. 1, 1:-1:0 (flange) and 2:1:0 (wall). And in the Figure 3, stresses σ_s and σ_w (Fig. 1) in three directions are shown for two kinds of aluminum sheets. The calculated directional dependencies of these stresses are in good agreement with measured ones. It can be predicted that the failure will be occur in the direction in which the difference between stresses σ_s and σ_w is the smallest. In the practical drawing of the sheets, the failure was observed in 0 for the A5052-H22 and 0 or 45 for the A1100-O.

Strain distribution

When a circular blank is drawn into a cup, in general the blank does not deform axisymmetrically, because a sheet

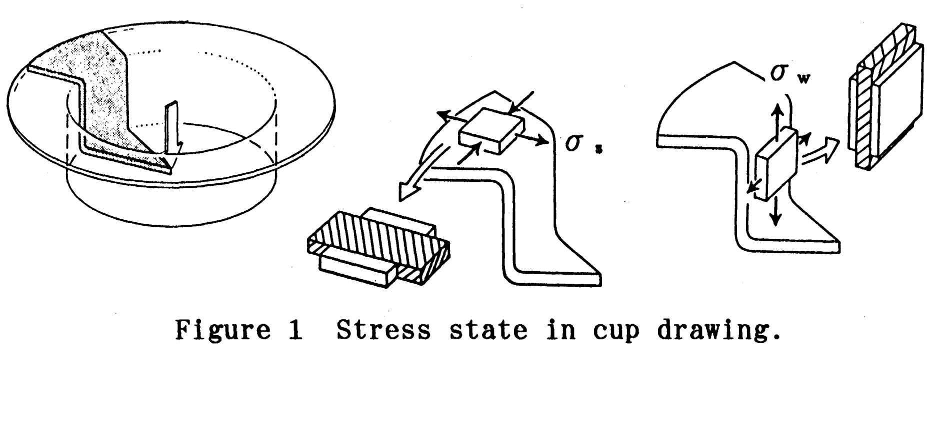


Figure 1 Stress state in cup drawing.

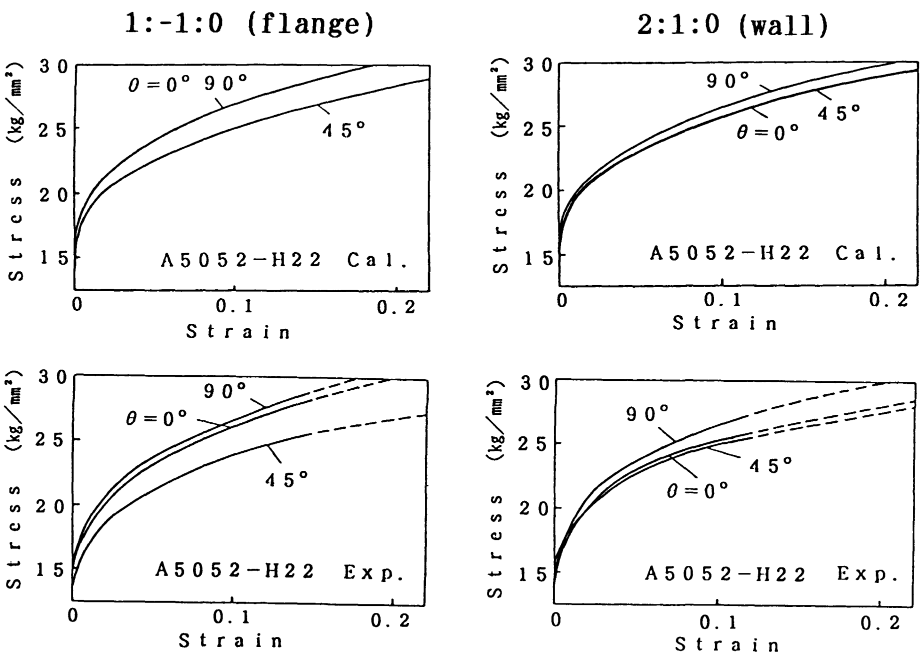


Figure 2 Equivalent stress-strain relations.

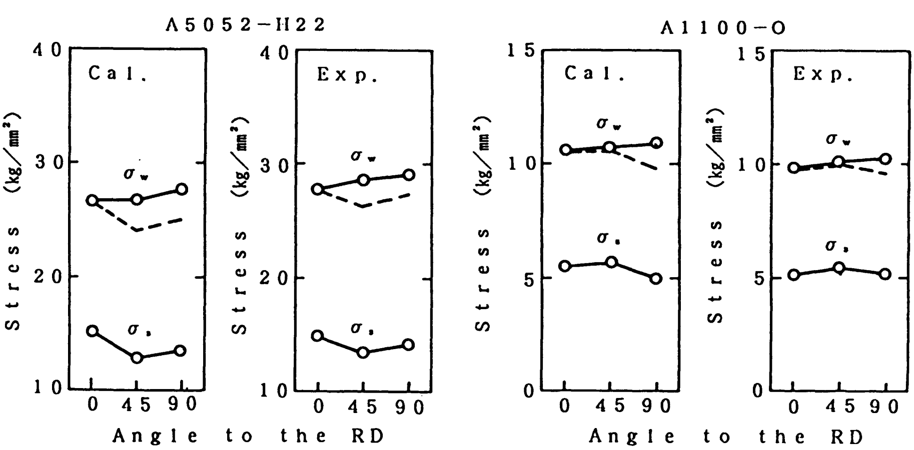


Figure 3 Directional dependency of stresses σ_s and σ_w .

metal has an anisotropic property. In order to make clear some problems in deep drawing of the sheet, it is necessary to know the strain behavior in the brank during drawing.

when an initial radial point of Ro on the blank is deformed to R during or after drawing, an average strain is calculated in assuming of a constant volume.

$$\bar{\varepsilon}_c = \ln(R/R_0) \qquad (3)$$

Then the directional variations of the circumferential (ε_c)

and radial (ε_r) strains are calculated using $\varepsilon(\alpha)$ in Eq.(2) under the stress state of 1:-1:0.

$$\varepsilon_c(\alpha)=C\cdot\varepsilon(\alpha),\ C=\bar{\varepsilon}_c/\bar{\varepsilon}(\alpha),\ \varepsilon_r(\alpha)=-\varepsilon_c(\alpha) \qquad (4)$$

where α is the angle to the rolling direction and $\bar{\varepsilon}(\alpha)$ is an average value along a circumference.

The calculated strain was compared with the mesured one under cup drawing of 100mm diameter. Figure 4 shows the strain distribution of some initial radial points after drawing. Figure 5 shows the developing of strain distribution at a given radial point during drawing. Although the calculated strain is smaller than that of mesured one, especially the circumferential strain is in good agreement.

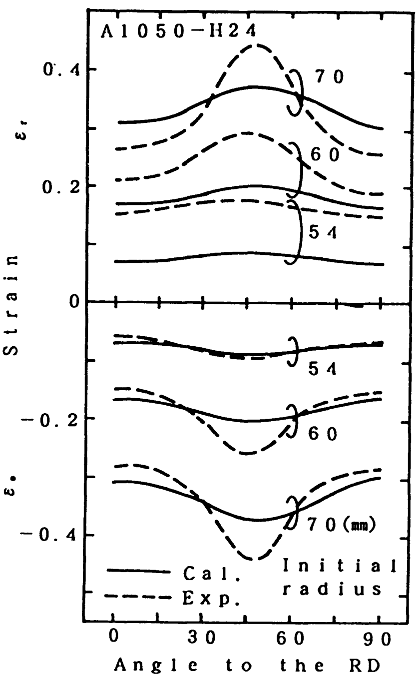


Figure 4 Strain distribution in wall of drawn cup.

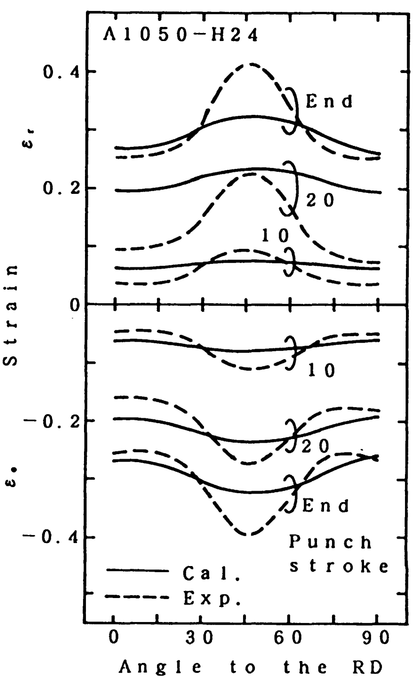


Figure 5 Strain distribution in flange during drawing.

Earing in drawn cup

The earing pattern of a drawn cup is predictable qualitatively from the texture or mechanical properties such as an r value, but is not quantitativly. Here the earing, that is a distribution of a cup height along a circumferefce is calculated for various drawing conditions.[2)]

Under the drawing condition shown in Figure 6, the cup height at each point along a circumference, h, is calculated using the $\varepsilon_r(\alpha)$ in Eq.(2) under the stress state of 1:-1:0.

$$h(\alpha)=(h_w/\bar{\varepsilon}_r(\alpha))\cdot\varepsilon_r(\alpha)+r_p+t_o \tag{5}$$
$$h_w=(R_b^2-R^2)/(R_p+R_d)$$
$$R^2=2(r_p+t_o/2)^2+(r_p+t_o/2)(R_p-r_p)\pi+(R_p-r_p)^2$$

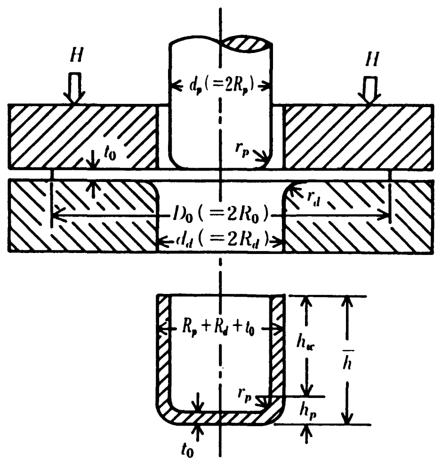
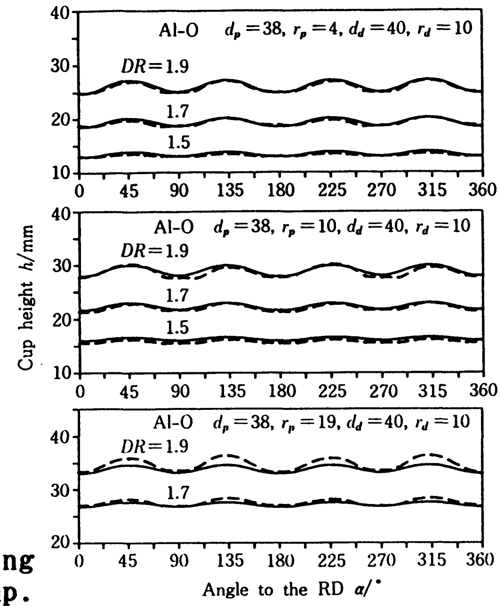
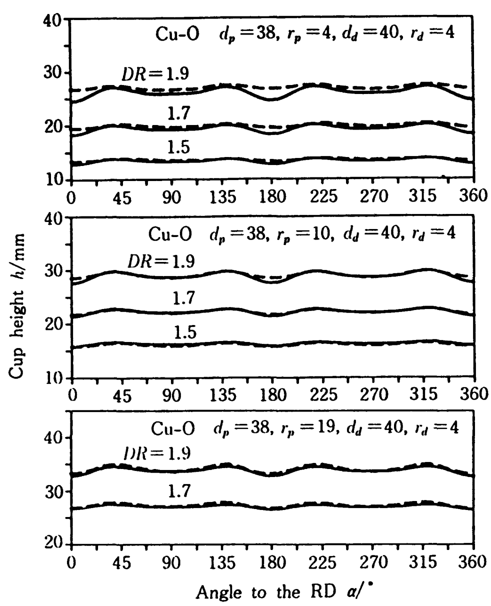


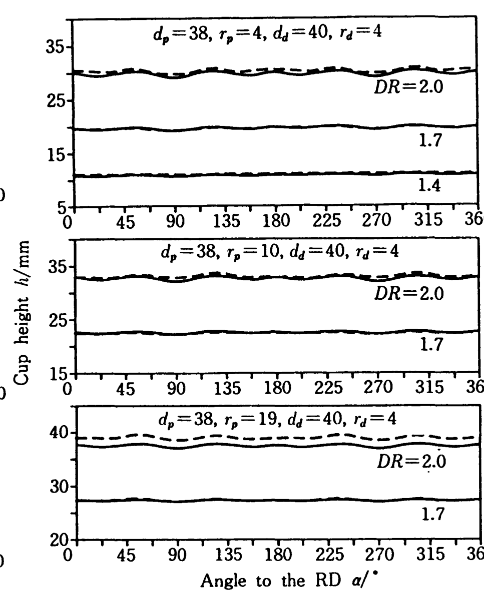
Figure 6 Dimensions of drawing tool, blank and drawn cup.



(a) Annealed aluminum



(b) Annealed copper



(c) mild steel

Figure 7 Calculated (solid) and measured (broken) earing of drawn cups.

where $\bar{\varepsilon}_r(\alpha)$ is an average value along a circumference.

Figure 7 shows calculated and mesured earing for some aluminum, copper and steel sheets. It can be found that calculated and measured earing are quantitativly in very good agreement.

Blank for non-ear drawing

Predicting a blank contour for non-ear cup drawing is vary useful for anisotropic sheet metals. On the base of above mentioned results of earing, the blank contour is predictable as follows for a required cup height h under the drawing condition of Fig.6.

$$R_o(\alpha) = h_w(\alpha)\cdot(R_p + R_d) + R^2 \tag{6}$$

$$h_w(\alpha) = (h - r_p - t_o)\cdot\bar{\varepsilon}_r(\alpha)/\varepsilon_r(\alpha)$$

Figure 8 shows the calculated blank contour for the aluminum sheet shown in Fig.7. Figure 9 are cups drawn from the calculated blank and circular blank. The cup drawn from the calculated blank has small uneven rim, because the blank was handmade. However the earing is much smaller than the cup drawn from the circular blank.

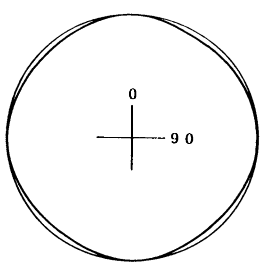


Figure 8 Calculated blank contour.

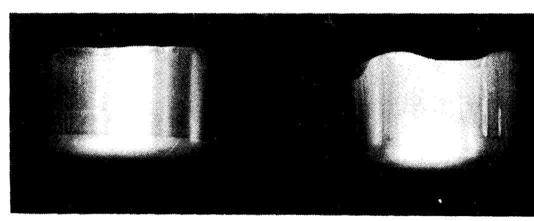


Figure 9 Drawn cups from circular and non-ear blanks.

CONCLUSION

The quantitative simulations of some macroscopic phenomena in a deep drawing process were carried out successfully using its texture data. The present simulation is useful for not only measured texture but also imaginary one. Connecting other computer simulation for the texture developing in a manufacturing process, the development of a new manufacturing process to produce a high-grade sheet metal will be possible by use of a computer system.

References

1. N. Kanetake and Y. Tozawa, Proc. ICOTOM 8,(1988),1005.
2. N. Kanetake and Y. Tozawa, Textures and Microstructures,7(1987),131.