# Study on the deformation theory of a parabolic part based on solid granules medium forming

Xiang-dong Jia, Chang-cai Zhao
Yanshan University

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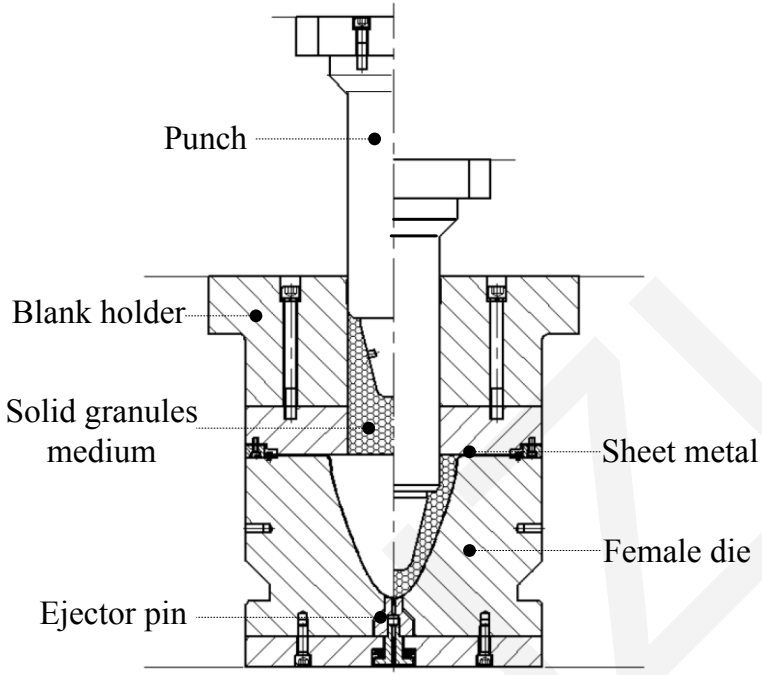
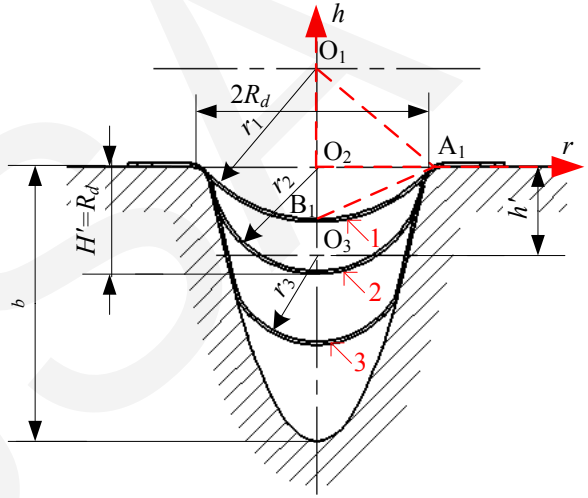
# 1. Introduction

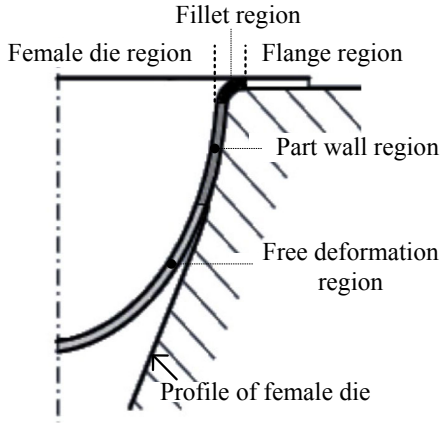
## *Parabolic parts forming process based on SGMF*




Schematic diagram of sheet metal drawing based on SGMF




Different deformation stages of sheet metal




The deformation regions of the sheet metal

weighted sum

**Drawing weight** ⟹ $\alpha = f_1(\Delta S) = \frac{\Delta S_d}{\Delta S_a} = \frac{\Delta S_f}{\Delta S_a}$

**Bulging weight** ⟹ $\beta = f_2(\Delta S) = \frac{\Delta S_b}{\Delta S_a}$

**Drawing weight is defined as the proportion of the deformation caused by conventional drawing in the whole deformation in female die region, represented as $\alpha$. .**

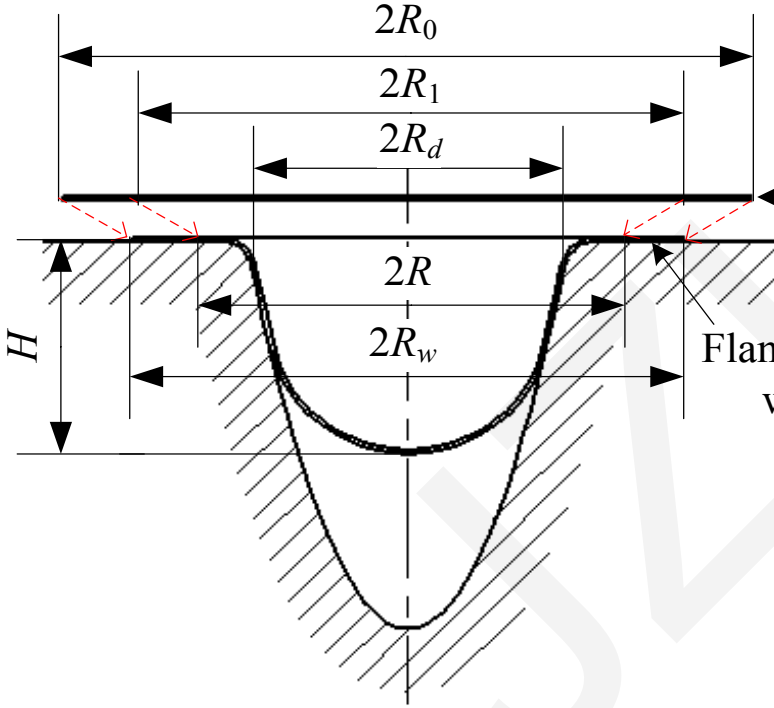
**Bulging weight is defined as the proportion of the deformation caused by bulging in the whole deformation in female die region, represented as $\beta$.**

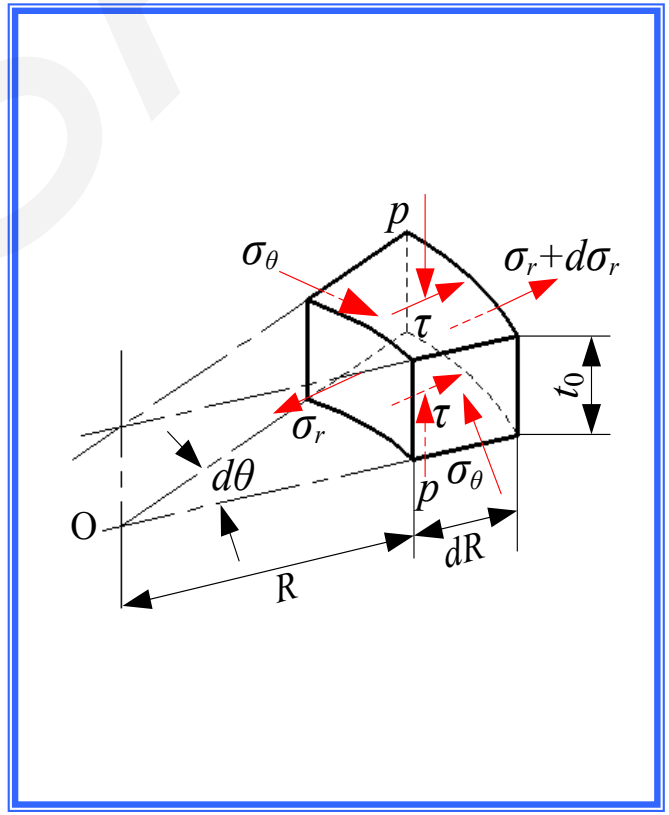
# 2.Theoretical Model

## ◆ Deformation analysis of flange region

$$\varepsilon_\theta = \ln\frac{2\pi R}{2\pi R_1} = \ln\frac{R}{\sqrt{R_0^2 - R_w^2 + R^2}}$$

$$\varepsilon_r = -\varepsilon_\theta = -\ln\frac{R}{\sqrt{R_0^2 - R_w^2 + R^2}}$$

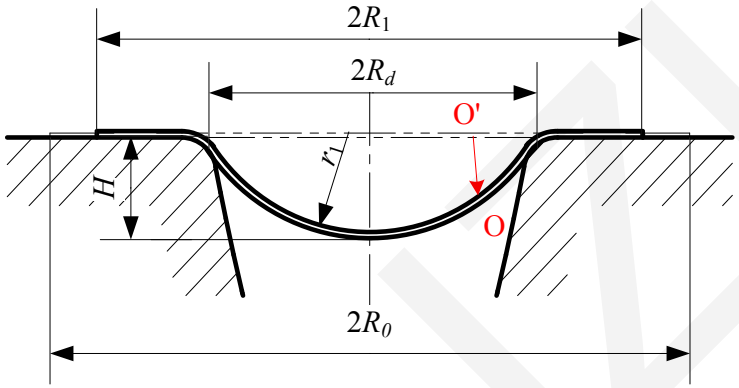


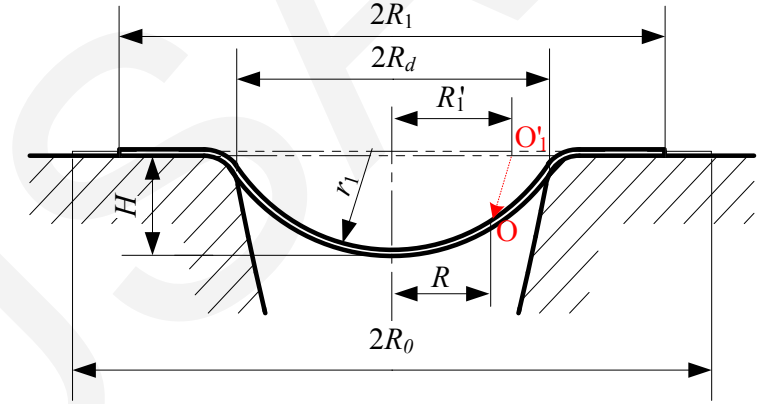

**the deformation of flange during deep drawing**

## ◆ Deformation analysis of female die region with a forming height $H \leq R_d$

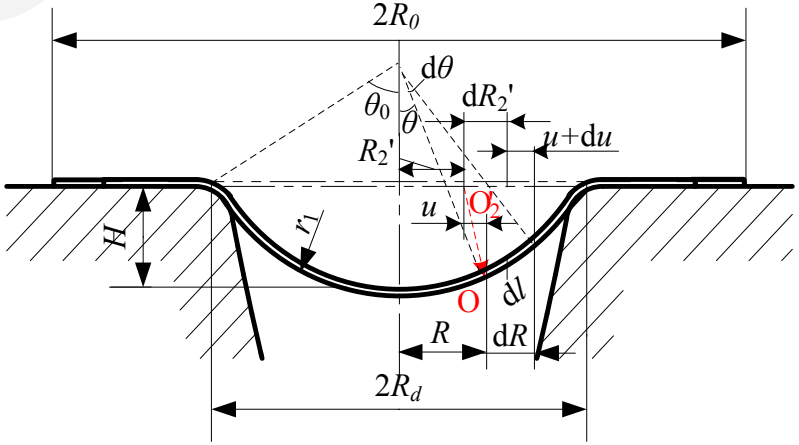
$$\begin{cases} \varepsilon_\theta = \alpha\varepsilon_\theta^d + \beta\varepsilon_\theta^b \\ \varepsilon_r = \alpha\varepsilon_r^d + \beta\varepsilon_r^b \\ \varepsilon_t = \beta\varepsilon_\theta^b \end{cases}$$




The deformation figure of sheet metal with a forming height $H \leq R_d$



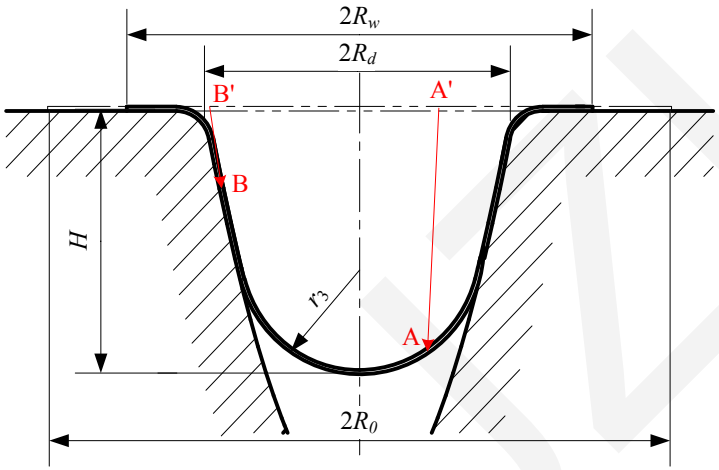

Single drawing deformation ($H \leq R_d$)



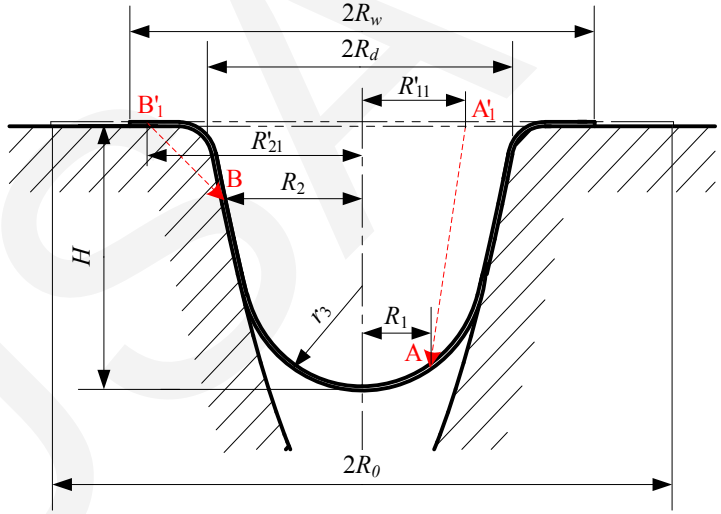

Single bulging deformation ($H \leq R_d$)

## ◆ Deformation analysis in female male die region with forming height $H>R_d$

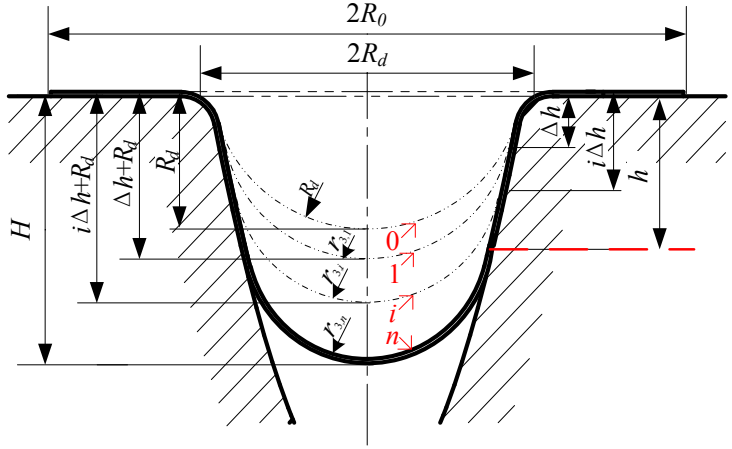
$$\begin{cases} \varepsilon_\theta = \alpha\varepsilon_\theta^d + \beta\varepsilon_\theta^b \\ \varepsilon_r = \alpha\varepsilon_r^d + \beta\varepsilon_r^b \\ \varepsilon_t = \beta\varepsilon_\theta^b \end{cases}$$




The deformation figure of sheet metal with forming height $H>R_d$




Single drawing deformation ($H>R_d$)




Single bulging deformation ($H>R_d$)

# 3.Experiment Research

➢experimental method

Schematic diagram

1

2

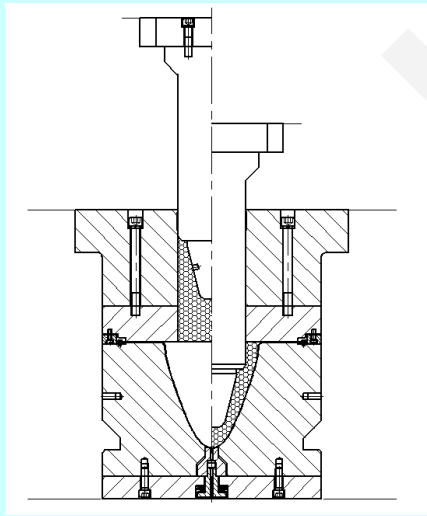
flexible male die drawing experiment

formed workpieces

3

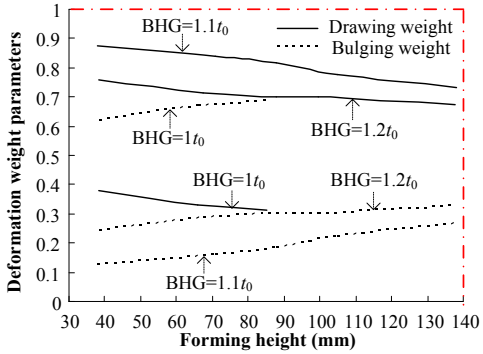
4

measurement

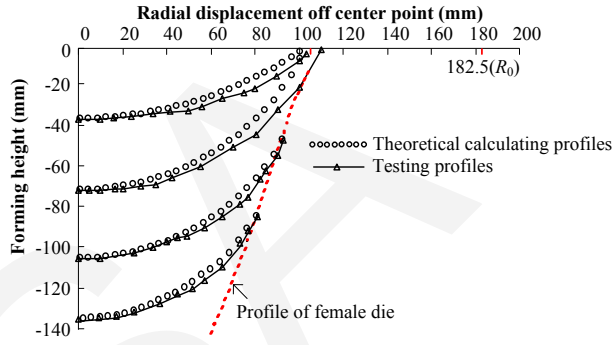


*H*=38mm *H*=71mm *H*=105mm *H*=138mm Formed part

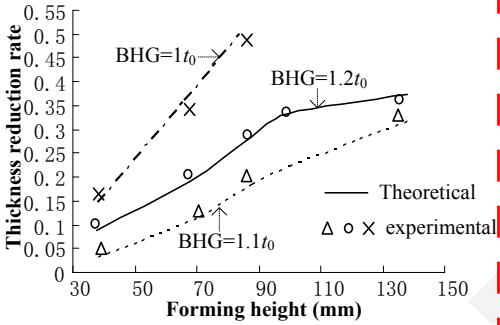
# 4.Results and discuss



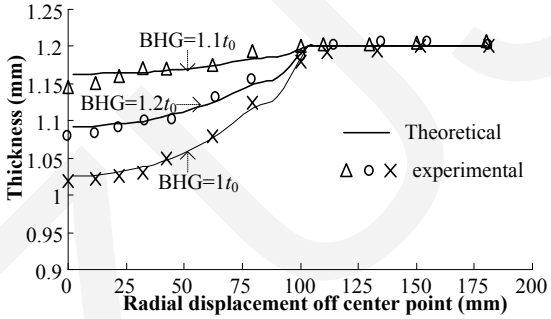

Curves of deformation weight parameters



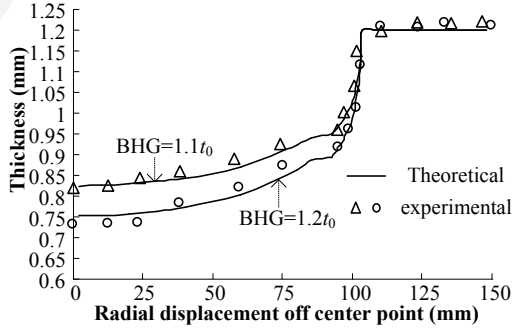

Profiles of workpieces in female die region at different forming stages



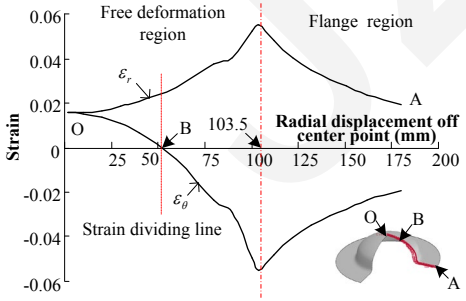

Curves of reduction rate in the forming process



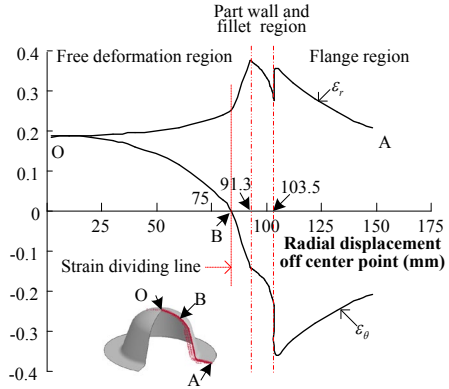

The thickness distribution curves for *H*=38 mm




The thickness distribution curves for *H*=138 mm




Distribution of strain at forming height of 38 mm




Distribution of strain at forming height of 138 mm

# 5.Conclusion

01 The larger the drawing weight is, the smaller the wall thickness difference of the formed workpiece becomes. However, the effect of the bulging weight is opposite.

02 The deformation of the flange region and the female die region of the parabolic part with drawing weight and bulging weight.

03 The forming height limit can be improved by setting reasonable forming conditions, increasing the drawing weight and decreasing bulging weight.