Available online at www.sciencedirect.com
ScienceDirect
Trans. Nonferrous Met. Soc. China 26(2016) 1251−1258
Transactions of Nonferrous Metals Society of China
www.tnmsc.cn

Influence of blank holder type on drawability of 5182-O aluminum sheet at room temperature

You-gen WANG[1], Guang-sheng HUANG[1,2], Ding-kai LIU[1], Lin CHEN[1], Ting-zhuang HAN[1], Jian PENG[1], Fu-sheng PAN[1,2]

1. State Key Laboratory of Mechanical Transmission, College of Materials Science and Engineering, Chongqing University, Chongqing 400044, China;
2. Chongqing Academy of Science and Technology, Chongqing 401123, China

Received 4 June 2015; accepted 22 March 2016

Abstract: To study the influence of blank holder type on the drawability of 5182-O aluminum sheet at room temperature, the flat blank holder and curved blank holder were employed during the deep drawing process. The microstructures were characterized by optical microscopy (OM). The results reveal that the limiting drawing ratio (LDR) of 5182-O aluminum alloy sheet is 1.7 using the flat blank holder. The drawn cup have severe earring. Compared with using flat blank holder, the LDR of 5182-O aluminum alloy sheet is enhanced to 2.0 using curved blank holder. In addition, the earring ratio also reduces and flange wrinkling is prevented when the curved blank holder is used. These are due to a more uniform sheet flow in different directions with curved blank holder.

Key words: 5182-O aluminum alloy; deep drawing; blank holder; earring; wrinkling

1 Introduction

As the light metal structural materials, magnesium alloys and aluminum alloys have recently attracted a lot of research interests because of their potential application on lightweight structural components [1−4]. However, due to the limited available slip systems of a hexagonal close packed (HCP) crystal structure [5], the poor plasticity and ductility of magnesium alloy restrict its wide applications [6]. Different from magnesium alloy, the advantages of high specific strength, excellent mechanical properties and recycling potential make aluminum alloy become a promising light material [7]. Especially, the 5000 series aluminum alloys are suitable for the application of auto-industry [8], owing to their medium strength, molding properties, low density, weldability and excellent corrosion resistance. However, owning to the planar anisotropy, flange earring is an important forming defect in the deep drawing process [9]. Moreover, the room temperature formability restricts increasing use of aluminum alloys compared with steels [10].

Aluminum sheets produced by rolling processes exhibit a preferred orientation which leads to a plastic anisotropy, expressed by the r-value. It is known that the r-value influences not only the drawability of the sheet in deep drawing, but also the uniformity of deformation in stamping. NIRANJAN and CHAKKINGAL [11] found that the drawability of 1100 aluminum alloy increased with the increase of r-value in groove pressing experiment. GHOSH et al [12] found that the height of ears of aluminum alloy was reduced with increasing r-value in warm deep drawing experiments. Deep drawing is an important and popular forming process for the production of flat components. Therefore, many studies focused on improving the drawability of aluminum alloys. LANG et al [13,14] found that the drawing ratio of AL6016-T4 could reach 2.46 during the hydrodynamic deep drawing assisted by radial pressure. NAMOCO et al [15,16] investigated the mechanical properties of aluminum alloy sheets. They found that the technique of bulging and embossing improved the deep drawability and the bending strength of aluminum alloy sheet.

Although many studies have been conducted to improve the deep drawability of aluminum alloys at room temperature, the earring and wrinkling still cannot

Foundation item: Project (CDJZR14130009) supported by the Fundamental Research Funds for the Central Universities, China
Corresponding author: Guang-sheng HUANG; Tel: +86-23-65112239; Fax: +86-23-65102821; E-mail: gshuang@cqu.edu.cn
DOI: 10.1016/S1003-6326(16)64225-5

be avoided. MORI and TSUJI [17] demonstrated that the limiting drawing ratio (LDR) of rolled AZ31 magnesium alloy sheets increased to 1.75 by the ring-shaped projection provided by blank holder. ZHANG et al [18] found that flange edge fracture was prevented using a ring-shaped blank holder. These were because the curved blank holder could offer a pressure onto the edge of sheet passing through the die corner. Compared with magnesium alloys, the flange wrinkling and the flange earring appear more easily in aluminum alloys during deep drawing. However, the effect of blank holder type on the deformation behaviors of aluminum alloy sheet in deep drawing is rarely researched, especially on the flange earring and the flange wrinkling. In this work, the effect of flat blank holder and curved blank holder on the deformation behaviors of 5182-O aluminum sheet in deep drawing at room temperature was investigated, and the microstructure evolution, LDR, thickness distribution, tool configuration, anisotropic effect, as well as wrinkling behavior and earring phenomenon were studied.

2 Experimental

The as-rolled commercial 5182 aluminum alloy sheets with a thickness of 1 mm were provided by Southwest Aluminum Group Co., Ltd., of China. The 5182 aluminum sheets were annealed at 330 °C for 2 h followed by air cooling. The composition of this alloy is shown in Table 1.

Table 1 Main composition of 5182-O aluminum alloy (mass fraction, %)

Si	Mg	Fe	Mn	Cr	Al	Cu
0.2693	3.9742	0.2436	0.3344	0.0693	95.0419	0.0673

According to General Administration of Quality Supervision, Inspection and Quarantine of China (AQSIQ) Standard GB/T228−2002, 5182-O sheets were cut into dumbbell-shaped tension specimens with 40 mm in gauge length, 10 mm in gauge width and 1 mm in gauge thickness which were machined at the angles of 0°, 45° and 90° along the rolling direction (RD). Uniaxial tensile tests were carried out on a CMT6305−300KN electronic universal testing machine with a strain rate of 1×10^{-3} s^{-1} at room temperature. The strain hardening exponent (n-value) is determined from the uniform plastic deformation region of the tensile stress−strain curve. The n_{avg} is the weighted average of n-values in three directions. This is defined as follows:

$$n_{avg}=(n_0+2n_{45}+n_{90})/4 \tag{1}$$

where n_0, n_{45} and n_{90} stand for the n-values along 0°, 45° and 90° to rolling direction, respectively. Lankford value (r-value) is calculated by the thickness strain and width strain at the deformed strain of 15%. The normal anisotropy coefficient r_{avg} is the weighted average of r-values in three directions. This is defined as follows:

$$r_{avg}=(r_0+2r_{45}+r_{90})/4 \tag{2}$$

Δr is the planar anisotropy and defined by

$$\Delta r = (r_0+r_{90})/2-r_{45} \tag{3}$$

where r_0, r_{45} and r_{90} stand for the r-values along 0°, 45° and 90° to rolling direction, respectively.

The circular blanks with different diameters were machined from 5182-O aluminum sheets for deep drawing tests. The schematic of deep drawing process is shown in Fig. 1, where the blank holders in Figs. 1(a) and (b) are flat blank holder and curved blank holder, respectively. Deep drawing tests were conducted using the flat blank holder with a constant force from 3 to 10 kN, which corresponded with different blank sizes. However, using the curved blank holder, the force was reduced to a constant value from 1.5 to 4 kN. The same stamping speed was set as v=5 mm/min. Anti-wear hydraulic oil was used as the lubricant. The diameter and the shoulder radius of the punch are 50.00 and 5.00 mm, respectively. The diameter of the die hole is 53.64 mm and the clearance between the punch and the die is 1.82 mm.

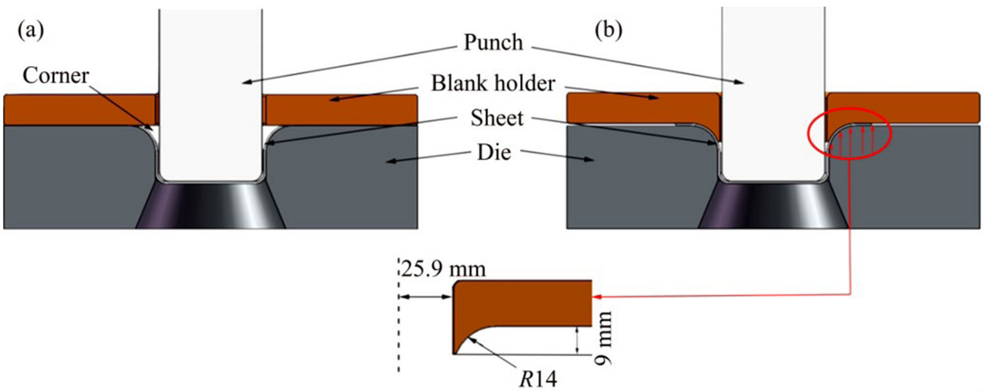

Fig. 1 Schematic of apparatus for deep drawing: (a) Flat blank holder; (b) Curved blank holder