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THE MANUFACTURING PROPERTIES OF GALVANISED STEEL SHEET WITH HEXAGONAL AND TETRAGONAL NETWORK OF CIRCLE HOLES

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Abstrak

Spesimen uji lembaran baja galvanis dengan tebal 0.8 mm diberi lubang lingkaran berdiamater dan antar lubang 2.5 mm dengan pola susunan tetragonal dan heksagonal. Sifat manufaktur bahan tersebut dipelajari melalui pengujian simulatif penarikan (drawing) dan rentang (stretching). Sebagai pembanding, dilakukan pengujian terhadap lembaran sejenis tanpa lubang perforasi. Dari hasil penelitian ini diketahui perbandingan sifat manufaktur lembaran perforasi dengan pola susunan lubang tetragonal dan heksagonal serta prediksi sifat intrinsik mampu tarik lembaran perforasi dengan menggunakan asumsi kontinum ekivalen.

Abstract

Galvanized steel sheet of 0.8 mm in thickness was drilled with circle holes of 2.5 mm diameter and spacing arranged in tetragonal and hexagonal pattern. The manufacturing properties of specimen were studied through drawing and stretching simulative test. It was concluded from the results that, at high ratio of punch to hole diameter (40/2.5), the drawing properties (LDR) of both square and hexagonal perforated sheet were slightly lower than that of solid sheet, while hexagonal perforated showing LDR somewhat higher than the square one. The stretching properties (LDH) of sheet, however, were much lower than that of solid sheet while the hexagonal perforated exhibiting LDH lower than the square one. Provided the efficiency factor was well defined, which was not effective in the present experiment, the intrinsic drawing properties might be indirectly determined through the simulative test by assuming the perforated materials as an equivalent continuum.

Keywords: Circle holes, manufacturing properties, stretching, drawing, galvanized steel.

Introduction

The development trends of metal forming technology are faced with an increasingly clear demand for products which are light, generating few waste by-products, and able to be be reintroduced to the material cycle completely with as few problems as possible [1,2]. Dealing with the light product, Kopp [1] revealed that the lightweight construction might be achieved by means of components, in which specific criteria has an especially high value in relation to their specific gravity. This call can be realized through high-strength lightweight materials, and by the use of structured metal sheets, hollow structures, and metal composites.

One alternative of weight saving is using perforated sheet. The appropriate holes design is expected to save weight without affecting the performance significantly. There are some studies in professional literature dealing with the analysis of forming processes of materials with a network of holes punched. Recent studies were performed by Nakamura [3] and Chen [4]. Nakamura investigated the behavior of mesh-punched sheet metal in deep drawing process. He studied the relationship of local and global deformation. Chen [4] explored the plastic deformation of perforated sheet, including finite element analysis and tensile testing. Muzykiewics et.al. [4] reported the basic information about the formability characteristic of perforated sheet by a set of laboratory experiment.

The present work is aimed at evaluating the effect of the holes configuration on manufacturing properties of perforated sheet. The results are expected to contribute the development of perforated materials for forming applications.

Experimental

The experiment was divided into two parts. The first step was to prepare specimen with a network of holes from galvanized steel sheet of 0.8 mm in thickness using a semi automated drilling machines. The second part was the assessment of manufacturing properties using 2 tonF tensile machine and 12 tonF universal s machine.

Deep drawing simulative test was performed using the following conditions [5]: 2 mm blank diameter interval (hand-cut), 40 mm diameter flat bottom cylinder, 42.5 mm diameter dies, oiled polyethylene lubrication, 1500 kg-f blank holder force, and low punch speed. Blankholder force was reduced to one third of the normal blankholder force of conventional deep drawing proportionally to the cut of area by the hole to give optimum material flow [5]. Stretching simulative test was carried out using 45 mm diameter hemispherical dome, oiled polyethylene lubrication, maximum clamping force (No Material Flow), and low punch speed.

It was revealed in ref. [6] that specimen with *drilled hole* has lower strength but higher plasticity than that with *punched hole*. The plasticity of drilled perforated occured at lower load and the strain hardening intensity at plastic region was considerably higher. These effects were more pronounced with larger strain hardening value. This experiment used drilled holes specimen as it was expected to exhibit better manufacturing performance.

Results and Discussion

Table 1 displays fundamental intrinsic properties of solid Galvanized Steel Sheet. The values that were measured in three directions give the general idea about the basic mechanical and manufacturing properties. The tensile strength is related to the necessary load to initiate deformation whereas the yield strength indicates maximum load to that can be usefully applied in a forming operation. The strength of materials as indicated by the UTS and YS value were signigicantly higher at rolling direction compared to that at diagonal and transverse direction whereas the total elongation that gives the general assumption about ductility is slightly lower at 45 direction.

The average values of strain hardening coefficient, n and plastic strain ratio, R are also depicted in table 2. The n

Table 1. Fundamental intrinsic properties of solid galvanized steel sheet 0.8 mm.

Dir.	eu	ef	YS	UTS
Degree	%	%	Kg/mm2	kg/mm2
0	29.57	34.21	35.32	46.04
45	25.37	32.43	30.77	31.21
90	24.24	34.21	30.07	30.63
Avr.	26.14	33.32	31.73	34.77

Table 2. Strain hardening coefficient and anisotropy planar of materials.

n	R	ΔR
0.242	1.174	-1.331

values indicate the ability of materials to withstand localized necking and hence the capacity of sheet to distribute strain uniformly before necking that also related to the uniform elongation values.

Table 3. presents two important parameters related to the drawabilty and stretchability of materials, which were obtained from simulative deep drawing and stretching test.

Drawing operation was characterized by the complex state of stress and strain. Circumferential stress works at the flange, while uniaxial and biaxial stress operate at the wall and bottom respectively. It is known from the analysis of stress and strain that, through thickness strength, which is measured by plastic strain ratio, predominantly determines the ability of component to be drawn without failure.

Previous experimental works performed by Muzykiewics [5] showed that the LDR of perforated sheet was equal to that of solid sheet although the height of the wall at similar drawing ratio might be different due to the closing of holes subjected to circumferential compressive stresses. The present experiment, however, showed that the perforated sheets exhibited slightly lower LDR than the solid one by 6.7% and 2.2%, while the LDR of hexagonal pattern was higher than that of tetragonal one by 4.5%.

The difference between these two experimental studies was likely due to the difference of process parameters, particularly tools geometry. It was known from prior works that the ratio of puch to holes diameter of prior experiment was 31/3 whereas that of present experiment was 40/2.5. It might be assumed that the present of the holes was more significant with the larger ratio of puch to hole.

LDR has a strong relationship with normal anisotropy, R, as known from either mathematical analysis by a number of simplifying assumptions or laboratory experiment [7-9]. With respect to the perforated sheet, two approaches may be made to analyse the plastic deformation of perforated sheet [4]. The first analysis treat the perforated sheet as an equivalent continuum that are compressible and anisotropic whereas the second approach observes the perforated sheet

Table 3. Simulatif properties of non-perforated and (drilled) perforated sheet

Specimen	LDR	LDH (mm)
Non perforated	2.25	3.25
Square perforated	2.1	1.325
Hexagonal perforated	2.2	1.47

as two phase materials with a large number of voids. It was known that the equivalent continuum model is more appropriate to be employed in global analysis whereas two-phase model is more accurate to describe local deformation but more difficult to be employed in global analysis.

By using simplying assumption and global analysis or equivalent continuum approach, the plastic stain ratio, R, of perforated sheet, which are difficult to measure using plastic strain ratio analysis of tensile specimen might be indirectly determined from the simulative drawing test. A similar grade solid sheet can be used as a benchmarking giving the effiency factor of the process.

It was known that planar anisotropy might be related to the height and direction of ears. It was revealed in ref. [7] that the height of ears increases proportionally with the increase of planar anisotropy as large as 15-20% from the height of cup. It is more practical to measure planar anisotropy, by measuring the ears height on a standard cup and expressing the index as the percentage of the mean height [8, 9].

It was known from prior studies that the variation of simulative test might be caused by low diameter of penetrator, uncontrolled flow of materials from the flange, and inconsistent lubrication [4]. The present experiment used higher penetrator to avoid excessive bending for thicker sheet, and used higher clamping force and appropriate die clearance to control the flow of materials. Oiled LDPE was expected to give more consistent lubrication as a result of solid-film lubrications mechanism. The mechanism, however, was not performed, because the film was stick to the dies and wrinkle [11]. It was therefore not possible to obtain efficiency factor of drilled perforated simulative experiment from similar solid specimen.

Ears were identified in both perforated and solid sheet in prior studies [5]. Unlike the solid sheet that produces 4 ears, the hexagonal exhibited 6 ears. The anisotro-py planar of perforated sheet may be characterized from the height and direction of ears. The characteristic of ears was not clearly identified in present experiment, and thus was excluded in the discussion.

It was revealed from stretching simulative test that the LDHs of both perforated sheets were significantly lower than that of solid sheet by 54.8% and 59.2%. The LDH of square perforated was lower than that of hexagonal perforated by 9.9%.

Conclusion

It was concluded from the results that, for high ratio of punch to hole diameter, the drawing properties (LDR) of both square and hexagonal perforated sheet were slightly lower to that of solid sheet, while hexagonal perforated having LDR slightly higher than the square one. The stretching properties of perforated sheet however were much lower than that of solid sheet while the hexagonal perforated having stretching properties (LDH) lower than the square one. Provided the efficiency factor was able well defined, which was not effective in the present experiment, the intrinsic drawing properties might be indirectly determined from the results of the simulative test by assuming the perforated materials as an equivalent continuum.

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