Sborník vědeckých prací Vysoké školy báňské - Technické univerzity Ostrava
číslo 1, rok 2006, ročník LII, řada strojní
článek č. 1492

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CREATION AND MEASUREMENT OF CIRCULAR GRIDS FOR FLAT FORMING

VYTVÁŘENÍ A MĚŘENÍ DEFORMAČNÍCH SÍTÍ PRO PLOŠNÉ TVÁŘENÍ

Abstract

Contribution concerns circular grids which are used at analysis of deformation process, verification of computer simulation results and at experimental determination of forming limit diagrams. Photo-chemical etching of circular grids on sheet-metal blanks with the use of currently accessible means is described. In second part of the contribution the photographic method of circular grids measurement with the use of digital camera and computer is described.

Abstrakt

Článek se týká deformačních sítí, které se používají při analýze deformačního procesu, ověřování výsledků počítačové simulace a při experimentálním určování diagramů mezních deformací. Je popsáno foto-chemické leptání deformačních sítí na polotovarech z plechu za použití běžně dostupných prostředků. Ve druhé části článku je popsán fotografický způsob měření deformačních sítí s využitím digitálního fotoaparátu a počítače.

1 INTRODUCTION

Principle of circular grids method consist in creation of circular grid at sheet-metal blank before drawing and evaluation of its deformation at any moment or after stamping drawing operation in stamping tool. Purpose is to get bases for deformation process analysis. Circular grid must minimally influence friction conditions, must not have notch effect, must be resistant against abrasive wear and lubricant, must have elements with accurate dimensions and shape.

For experimental determination of deformation layout the circular grid from circles is mostly used (Fig. 1). The advantage of this network is that directions of main stress and strain are identical with the directions of main axes of ellipses, to which the initial circle elements are deformed.

The size of circles to be used depends on the expected variation of strain in the formed part. If there is a rapid variation of strain then small grid circles are required in order to locate and measure the peak strain. If the variation of strain is gradual then larger grid circles can be used. For most purposes grid circles having a diameter of 2 to 20 mm are used.

2 EVALUATION OF DEFORMATIONS AT FORMING

It is possible to evaluate the changes of circular grid after forming from many points of view and by various manners, from the simplest to the intricatest.

The values of main strains can be calculated from formulae:

$$\varepsilon_1 = \frac{L_1 - L_0}{L_0} \cdot 100 \qquad (\%) \qquad (1)$$

$$\varepsilon_2 = \frac{L_2 - L_0}{L_0} \cdot 100 \qquad (\%) \qquad (2)$$

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where L_0 is the initial diameter of circle element, L_1 is the length of main axis of ellipse, L_2 is the length of secondary axis of ellipse (see Fig. 1).

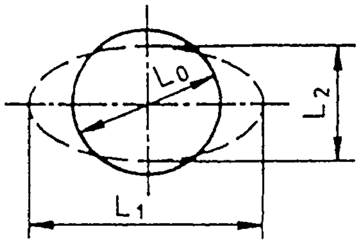

Fig. 1 Circular element of circular grid before forming (solid line)
and after forming (dash line)

After deformation of circular element of circular grid from the lengths of major and minor axis of descending elipse the values of main logarithmic deformations can be computed:

$$\varphi_1 = \ln \frac{L_1}{L_0} = \ln(1 + \varepsilon_1) \tag{3}$$

$$\varphi_2 = \ln \frac{L_2}{L_0} = \ln(1 + \varepsilon_2) \tag{4}$$

$$\varphi_3 = -\varphi_1 - \varphi_2$$

φ φ φ

$$S \;= \frac{\pi \cdot L}{\quad} \tag{6}$$

The area of the element of circular grid after forming, i. e. the area of ellipse:

$$S = \pi \cdot L_1 \cdot L_2 \tag{7}$$

The law of volume conservation in the place of element of circular grid:

$$S_0 \cdot s_0 = S \cdot s \tag{8}$$

The thickness of sheet-metal in the place of element of circular grid after forming:

$$s = \frac{s_0 \cdot L_0^2}{4 \cdot L_1 \cdot L_2} \tag{9}$$

From measured and computed main logarithmic deformations the main strains σ_1, σ_2 in given volume element of stamping can be computed.

3 METHODS OF GRID MARKING

It is possible to make circular grids by photographic method [1, 2], printing (serigraphy [3, 4], offset [1], rubber stereotyping [1, 5]), chemical etching [5, 6], electrolytic etching [7, 8], electroerosive sparker [1, 5], graving [5] and embossing [9, 10].

The differences among separate methods of circular grids making are in drawing thickness, reproduction accuracy, possibility to make network with small parameters, legibility after great plastic deformation, etc.

Every method, mentioned above, do not offer at practical use only advantages. That is why every method has its chracteristic and suitable use in practice.

The generally valid principle is, that such method of making circular grids is to be used, which guarantees getting of network with required quality and minimal cost.

4 PHOTO-CHEMICAL ETCHING OF CIRCULAR GRIDS WITH THE USE OF CURRENTLY ACCESSIBLE MEANS

Substance of this method is in creation of circular grid picture on metal surface with the use of photosensitive layer. This layer is exposed through negative of pattern by strong ultra-violet radiation and during developing it is dissolved at places of exposition. Very fine, sharp lines can be printed on the blank in this way. Non-coated areas in shape of circular grid elements are then etched and chemically or galvanically blacked.

4.1 Process of manufacture

a) Manufacture of circular grid pattern

- Drawing of circular grid (e. g. with the use of program AutoCAD). Advantage of utilization of drawing software is accuracy, speed at application of functions for drawing of multiple duplicating objects and possibility to draw any required shape of circular grid for given case. Printing is suitable to carry out in the best quality.
- Creation of negative of pattern by its copying to foil suitable for using at copiers, designed for projectors (copier must be set on function negative and maximal color purity). Negative of pattern has shapes of transparent circular grid, other areas are fully covered by colour. Proper places with non-perfect covering can be retouched, e. g. by fix.

b) Creation of circular grid on blank – this process is fully described in table 1.

Table 1 Process of circular grid creation on blank

No.	Activity name and description	Bath constitution, means	Materiality to 1 l H_2O (g)	Working conditions	
				temperature (°C)	time (min)
1	Degreasing to reaching wettability	paste „Primo“	-	45	5
2	Rinsing	water	-	45	2
3	Drying by air flow or dryer	-	-	-	-
4	Protection of one blank side by adhesive foil against reagents treating	adhesive foil	-	-	-
5	Spraying of photosensitive emulsion	POSITIV 20	-	20	-
6	Drying of emulsion (protect against light)	-	-	20	24 h
7	Placing of negative, loading by glass, exposition by ultra-violet radiation from distance 0,5 m	discharge lamp RVK 125 W	-	-	4
8	Developing, to wash layer by pad, checking of photosensitive emulsion dissolving	NaOH	10	20	2
9	Rinsing	water	-	20	2
10	Etching	$FeCl_3$	600	20	3
11	Rinsing	water	-	20	2
12	Chemical blacking	$FeCl_3$ $CuCl_2$ ethanol	5 3,5 90	20 - 40	10
13	Drying by air flow	-	-	-	-
14	Removing of adhesive foil	-	-	-	-
15	Removing of non-exposed layer of photosensitive emulsion	thinner C6000	-	-	-
16	Protection against corrosion	Konkor 101	-	-	-

It should be noticed that the etching boundary is very sharp. This is of great importance especially for large plastic deformations in order to be sure where a circle begins.

5 MEASUREMENT OF CIRCULAR GRID ELEMENTS

For objective evaluation of stress and strain by circular grids the separate elements of circular grid on stampings must be precisely measured. With regard to the fact, that the elements appears also on round and curved surfaces, its accurate measurement is difficult.

Some measurement methods respect stamping surface curvature, e. g. measurement by special gauge for measurement of lengths on curved surfaces from thin transparent foil on which basic straight line and subsidiary straight line, which are moderately concurrent, are made [10] or less exact measurement by flexible gauge with decimal scale.

Other methods do not measure arc length but its projection – due chord length. Size of systematic error is in this case dependent on radius of curvature of stamping surface R and length of measured arc L_1. For example for radius of curvature R = 25 mm and length of major axis of element of circular grid after deformation L_1 = 5 mm, difference $L_1 - t$ = 0,01 mm, where t is the length of arc chord. Error at strain compution is in this case negligible. At measurement on small radii of surface curvature it is necessary the systematic error include to measured value.

Method described below brings facilitation of toilsome measurement of circular grids, especially decreasing claims on visual abilities.

6 PHOTOGRAPHIC METHOD OF CIRCULAR GRIDS MEASUREMENT

Principle of this method is photographing of separate circular grid elements by digital camera by macrophotography method. Photographs are then like raster pictures inserted in program AutoCAD and there in large magnification on monitor measured with the use of program dimensioning.

6.1 Process of measurement by photographic method

a) Photographing of elements

Current digital cameras do not make possible photographing from so small distance that on photograph may be only one element of circular grid. That is why it is necessary the camera equip by supplementary lens. Picture size on photograph is dependent on distance of objective from photographed object. Constant distance is necessary to secure by distance ring and stop with hole diameter about 1 mm larger then maximal photographed element.

Apparatus diagram is on Fig. 2.

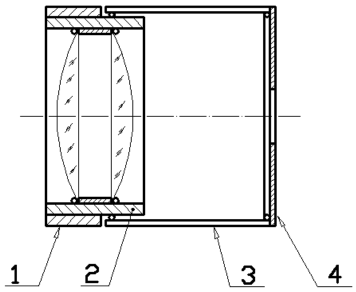

Fig. 2 Apparatus for photographing of circular grid elements
(1 – ring for fastening to objective or camera corpus,
2 – releasing body tube of supplementary lens,
3 – distance columns, 4 – stop)

b) Measurement of elements

Dimension value is dependent on picture insert scale. Considering that at computation of strain the ratio of element dimensions after and before deformation is used, it is not necessary to know the true elements dimensions, but for better notion it is convenient. That is why it is necessary to determine the inserting scale so, that dimension was accurate. Change of picture size by zooming carried out before dimensioning does not influence dimension size.

Correct inserting scale can be determined by photographing of known correct dimension, e. g. slip gauge width. First scale, selected by estimate, is then adjusted by ratio of dimension value and correct gauge dimension. This process is convenient to repeat for precise the scale and in the end to determine measurement errors. Achieved accuracy of measurement is 0,01 mm. Accuracy is kept when position and geometry of apparatus is kept.

After inserting of picture to file in program AutoCAD its enlargement to size suitable for dimensioning with the use of command „Zoom window“ is carried out. According to the fact, that the direction of dimensioned dimension is not mostly paralell with coordinate axes the command „Inclined dimension“ is used.

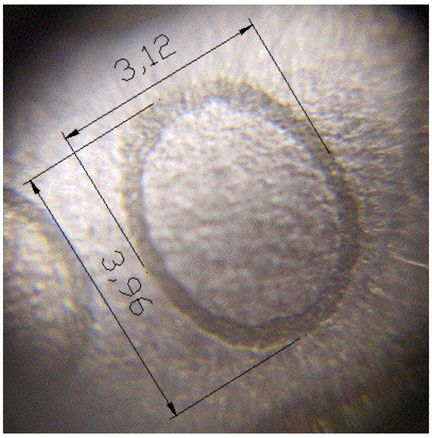

Fig. 3 Measured element of circular grid

7 CONCLUSIONS

Both methods of creation and measurement of circular grids described in this contribution were used for determination of strain distribution at test stampings and at experimental determination of forming limit diagram. In both cases a good availability in practice was confirmed - gained strain distribution was flowing, without oscillations caused inaccuracies of circular grid and its measurement.

Measurements and visualization of strain patterns make possible to locate and eliminate the causes of many breakage problems. Strain distribution analysis may be used to detect critical stampings, reduce production breakage, monitor die modification and evaluate material specifications.

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