A Photogridding Method for Strain Analysis During Plastic Flow

Muhammad Fazli Ilahi, Ph, D*

ABSTRACT

Experimental investigation of stress and strain play an important role in determining the strength charcteristics of a material. For some types of tests e. g. uniaxial tests, the determination of strain is not much complicated compared to the process involved for some other tests e. g. balanced biaxial tension tests, tube bending etc. Many methods have been used to determine the strains and the techniques are under constant study to enable investigators determine more accurate values of strain. For uniaxial and biaxial stress systems the photogridding method have been used for a long time but the quality of the grids are being improved by developing better methods of gridding. For determining the strain the distance between the grids are recorded during a deformation process for corresponding load or pressure. These values are then used to find the values of the strain for the corresponding stresses. A procedure of photogridding to produce distinct grids which will not be damaged by extreme deformation, grease or oil has been developed and described in this paper.

INTRODUCTION

The method of photogridding for the determination of strain distribution during a deforming process has been used for more than forty years. Brewer and Glassco [1] pointed out the limitations of previous work on metal forming due to the lack of a suitable technique to investigate local deformation. They suggested the use of photogrid technique which consists of photographing a pattern of lines upon a sensitized specimen from a high contrast negative. The specimen was sensitized by using a emulsion of photoengraving glue (4 parts by weight), water (28 parts), ammonium bichromate (1 part) and ammonia water ($\frac{1}{4}$ part). It is apparent that if lesser number of chemicals can be used to prepare the required emulsion the tech-

* *Assistant Professor, Department of Mechanical Engineering, University of Engineering & Technology, Dacca—2.*

nique of photogrid might be more attractive. Brewer [2] suggested the use of alcohol as a preservative for the emulsion.

Brown and Jones [3] mentioned the important properties that the photogrids should have. The grids should not be destroyed and should remain well defined after considerable straining or in contact with other medium. The technique of photogrid was used mostly during the Second World War. Wilson and Marin [4] used golfball paint to provide white elastic coating. Miller [5] used cold top enamel and Dyrite. He pointed out the fact that the grids can be photographed at intervals and strains can be analysed later after finishing the deforming procedure. But when deformations are carried out upto high values of strain the grids become blurred and the outline loses its sharpness. Also efforts were made to produce an emulsion which can be easily prepared and can give distinct grids which will withstand extreme deformation. Such a procedure using new type of chemicals has been outlined below.

GENERAL RULES AND SAFETY MEASURES

While working with the chemicals adequate ventilation is to be ensured and no carbon arc lamp should be used when handling trichloroethylene. Naked flames should not be used near the chemicals. Polythene gloves and protective eye shields should be used. There should be no daylight inside the room but the work area can be lit by filtered lamps. Loss of volatile solvents can be minimized by using narrow vertical stainless steel containers or glass and glazed earthenware. Copper, brass, zinc-lined or plastic containers are to be avoided. The specimens which are to be gridded should be scrupulosly clean aud distilled water should be used for washing. Subsequent steps should be carried out without delay.

PROCEDURE

The general procedure followed for photogridding are given below in sequence.

1. Surface Preparation

(a) The specimen should be cleaned by polishing paper of grade 400 which is used to rub the surface on which the grid is required.

(b) The surface should be rubbed with pumice powder with the help of cotton wool after wetting with water. The surface is clean enough when the film of water on the surface is without any discontiuuity.

(c) The pumice powder is thoroughly washed off with distilled water and the blank is dried by hot air dryer or in oven.

2. Surface Coating

(a) Coating chemical was prepared by mixing KMER* and KMER Thinner. The ratio of KMER to KMER Thinner (vol./vol.) can vary between 3: 1 and 1 : 1. For the present work 2 parts of KMER and 1 part of KMER Thinner were used and good results were obtained.

(b) Coating can be applied either by brush or turntable (equipped with potentiometer for changing the speed). Pouring of the mixture should be started at the center of the circular blank if a turn-table is used. Coating can be applied to some specimen by withdrawing the specimen slowly from a container containg the coating chemical or by using a sprayer.

3. Drying the Coating—Prebaking

(a) The coating is to be partly dried in air at room temperature for about 20 minutes until it is dry to the touch.

(b) It is to be further dried in an oven between 80-120°C (176—240 °F) preferably with air circulation for about 15 minutes.

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*KMER (Kodak Metal Etch Resist), KMER Thinner, KMER Developer and KPR Dye (Black) were supplied by KODAK Ltd., U. K.

4. Resist Exposure

The coating is exposed selectively to UV radiation using a photomaster negative with a black background. To prepare the negative a large drafting of the grid pattern should be made to reduce the drafting error and a photograph of it should be taken using a high contrast film. The original drawing is very important and any error on it will be reproduced on the grid. And films that are unaffected by temperature and humidity changes give better results for a long period. Four lamps having a power rating of 125 watts each were used, assembled in a steel cabinet. The lamps used were Philips APR 125 w 8L type. For correct positioning of the photomaster negative in the blank templates can be used if required. For good contact between the negative and the blank a piece of glass plate can also be placed over the negative. If vacuum can be created (e. g. by vacuum printing frame) between the negative and the blank better results may be expected. The exposure time was about 4 minutes and the distance of the lamps from the blank was 18 inches. For larger specimens greater distance is required for uniform illumination but the time required for proper gridding will also be higher. Longer exposure time gives blurred grids and lower exposure time gives faint images.

5. Development

After exposure the blank is slid in a stainless steel dish containing KMER Developer and should be left for about 2 minutes without agitation. After that the blank should be lifted and left in KPR Dye (Black) for 30 seconds to give distinct black grids. Then the blank is rinsed with spray jet of tap water. (If any scum remains it can be removed by immersing the blank in Isopropyl Alcohol for few seconds). Finally the blank is debunked in distilled water. At this stage the grid is weak and should not be disturbed,

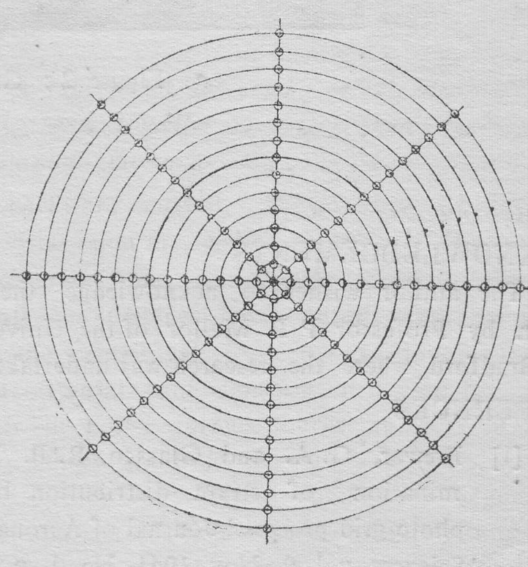
6. Drying the resist image—Postbaking

(a) The blank is to be dried in air for about 10 minutes.

(b) After drying the water drops with tissue paper very lightly it was further dried in an oven at about 120°C (248°F) for about 10 minutes. The temperature of the oven should not exceed 150°C. At this stage the grid is no longer weak and will not be damaged by rubbing action, deformation or by oil.

RESULTS AND CONCLUSIONS

The above technique was developed by using small specimens and rectangular grids and finally big circular 10 inch diameter blanks of Aluminium Killed Steel, Soft Brass and Soft Aluminium were deformed by unilateral hydrostatic pressure using the grid patterns shown in Figure 1, The deformed blank (Figure 2) presented no problem during the determination of the strain distribution. The grids were distinct even after fracture of the specimen and the method was also successfully used on tubes for bending tests.



PATTERN OF THE GRID SYSTEM

FIGURE : 1.

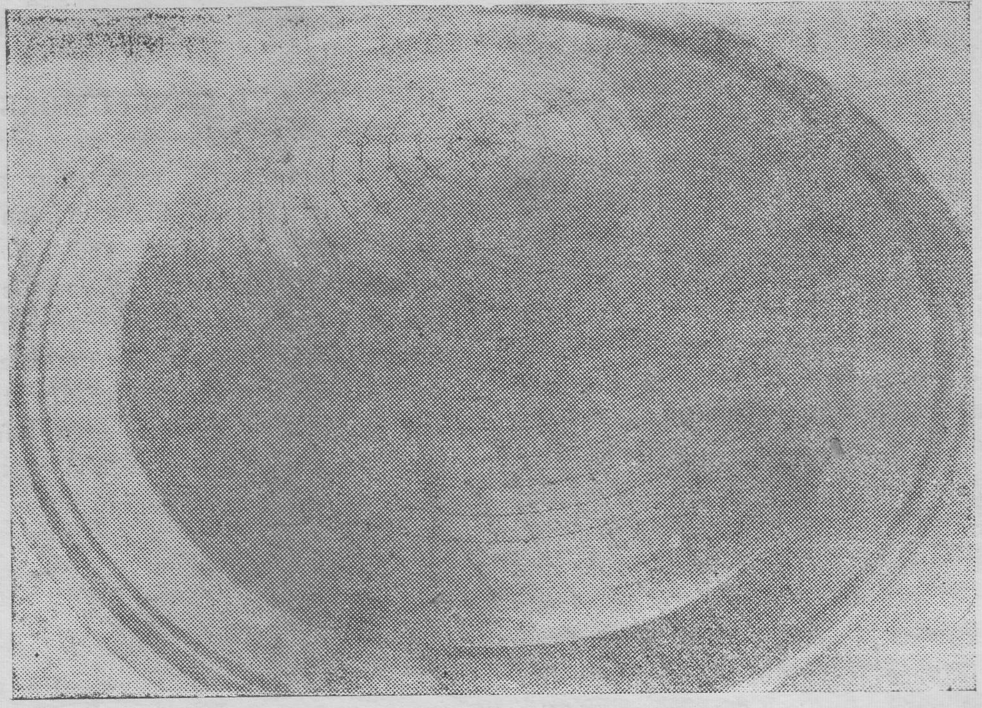


Figure 2 : Grids on a Deformed Blank

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