EVALUATION OF DRAWING PUNCH DECELERATION UNDER DYNAMIC LOADING BY MEANS OF PHOTOGRAMMETRY

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Abstract

At Department of engineering technology TU of Liberec were designed special device by means of which is possible to measure final limit diagrams through the use of shaped samples stretching by semi-spherical punch under its high impact velocity [1]. For common measurement is velocity set to correspond to the crash test’s velocities. During forming of shaped samples there is a very high deceleration of punch. By the help of two high-speed cameras was carried out measurement to gain two independent synchronized frames and videos of measured samples deformation by punch. The pressure of driving medium was set to the value 0,25 MPa which corresponds to punch’s impact velocity \( v = 19 \text{ m/s} \). For experimental part was used high-strength steel material CPW 800 which belongs into complex-phase steels group. Its thickness was 2,1 mm. Such kind of material is commonly used to produce crash parts of car-body. Diameter of used punch represented 100 mm. within the frame of complex measurement were gained basic mechanical properties of used material, forming limit diagram under described impact velocity and finally basic kinematical quantities during sample’s deformation. Evaluated was course of kinematical quantities of punch during forming process and time of samples deformation by means of punch. The aim of the article is to introduce new device for final limit diagram and give overview about results.

1. INTRODUCTION

To determinate limit deformation are nowadays using different more or less suitable methods by which are measured so-called final limit diagrams. Implementing of new technological processes into production and pre-production periods together with using very new or still developing materials brings new requirements onto measuring conditions, quantity and reliability of measured values. These days methods for measuring final limit diagrams do not take into account namely influence of strain rate which plays a very important role during forming and also influence of material forming history onto measured or used sheets limit deformation values. Basic method to determinate final limit diagram of thin sheets which is used at Department of engineering technology represents stretch shaped samples by semi-spherical punch of diameter 100 mm. Punch velocity is \( v_1 = 2,08 \cdot 10^{-4} \text{ m/s} \). [2]

2. METHODOLOGY TO EVALUATE INFLUENCE OF STRAIN RATE AND SIZE OF PRE-DEFORMATION ONTO LIMIT DEFORMATIONS

Influence of strain rate onto limit deformation is evaluated by means of tests on special devices. This tool enables to change holding force with regard to used material, energy and velocity of punch by means of its mass and compressed air regulation. Measurement procedure is in principle modified test of stretch shaved samples by semi-spherical punch. Samples loading velocity corresponds to velocity of frontal crash test. Impact velocity is \( v_2 = 19 \text{ m/s} \). Design of used device is shown in fig. 1. Limit deformation is for all used velocities measured in the range of seven different states of stress. Size deformation in major directions is gained by means of deformation mesh prepared by electrochemical etching onto testing samples. Deformation mesh consists in our case of overlapping circular elements with diameter \( d = 2 \text{ mm} \) with crosses...
and during deformation is strained in the single-purpose tool by semi-spherical punch. After achieving the pre-defined limit state are measured basic sizes of chosen strained elements of deformation mesh from that calculated major strains and finally designed final limit diagrams.

Fig. 1. Design of mounting tool
For identification pre-deformation influence onto material limit state are shaved samples deformed to 1/3 and 2/3 size of limit state, measured by the same method under punch velocity \( v_1 = 2,08 \times 10^{-4} \) m/s. There are possible two testing methods. Their principle is clearly shown in the fig. 2.

Fig. 2. Testing methods
In the first variant is direction of punch identical with the direction of punch which pre-deformed samples and in the other case is direction of punch opposite to pre-deformation punch direction. The way how to evaluate influence of pre-deformation and strain rate onto limit state for material CPW 800 is described in fig. 3.
3. PUNCH DECELERATION MEASUREMENT

Punch which realizes sample deformation is onto required velocity accelerated by compressed air. During own deformation is punch stopped during few milliseconds from impact velocity 19 m/s and subsequently reflected against initial impact direction. The aim was to determine courses of punch velocity and deceleration during forming of samples. Deceleration corresponds to braking effect of used samples. Because of this measurement was necessary to modify testing device so that was possible by means of two high-speed cameras to scan punch movement during forming. Into pressure “cannon” was prepared face
gap in which is possible during experiment see arm which was mounted onto used punch – see fig. 4. Onto this arm were placed reflective points which are subsequently scanned by two independent scanning cameras.

![Fig. 4. Scheme of punch with reflective points on extension arm](image)

For experimental part were used two high-speed cameras Redlake MASD HG-100K. Resolution of cameras was set to value 512 x 144 pixels. Frame rate f = 10 000 Hz. Firstly were carried out several measurements because of camera, lights and trigger adjustment. Then were carried out three measurements with the same parameters – it means air pressure and preexposure. Scanning of high-speed cameras was synchronized. By means of these cameras were measured position of reflective points placed onto punch arm (it means moving points) compared to position of reflective points placed onto pressure cannon (non-moving points) – see fig. 5. Individual values of points displacements were subsequently evaluated and measured were courses of velocity and deceleration of reflective points. Reflective points were marked by numbers from 1 to 3. All points were evaluated separately. With regard to range of this article are here shown only courses of kinematical quantities for point no. 1.

![Fig. 5. Movement of punch and reflective points in „cannon“ before impact onto sample](image)

In fig. 6 to 8 are shown coursers of position, velocity and acceleration upon time for point no. 2 during punch impact onto tested sample and during sample deformation.
4. RESULTS EVALUATION

Courses of individual kinematic quantities are shown in fig. 6 to 8. These courses are real data without using any filter for curves approximations. In fig. 6 is shown position for point no. 2 in dependence on time. From this graph is clear that courses for quantities are scanned from moment when punch is approximately 100
mm before surface of tested sample. From graph in fig. 7, where is shown course of impact velocity, respectively punch velocity during sample deformation, is evident that impact velocity of punch in the moment just before impact onto sample is all of 70 km/h. Above all from this graph is clear that sample deformation lasted till 2 ms. To such time corresponds max. 20 frames (video samples). Time value needed for sample deformation (or deformation time) represents 2 ms. To achieve limit state of sample (crack opening) is necessary very short time thus also value of strain rate is also very high. Course of punch deceleration during sample deformation is shown in fig. 8. From this figure is evident that punch deceleration achieves up to 2000 G. All described results are measured during deformation of full (circular) blanks. For other states of stress, when samples are shaped according [1], are results very similar even there are different kinematics quantities.

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LITERATURE
