Contact phenomena in micro-blanking

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SUMMARY: In the nearly future micro-blanking will be often used for manufacturing of semi-final micro-products. This determines close tolerances, very close clearance and high height to diameter ratio. Such conditions dramatically increase galling tendency on a free surface of a punch. In this paper the function, which defines this tendency is introduced. It utilizes geometrical process parameters. The proposed method is based on estimation of sliding distances distribution of the main contact types and giving them adequate weights. Adding all single (weighted) sliding lengths distributions it is possible to determine distribution of the galling tendency function. Micro-blanking of the 0.7 mm thick strip made of 304 stainless steel using 1 mm punch diameter with 0.03 mm clearance was analysed as an example.

Key words: Plastic Forming, Microforming, Contact Phenomena, Galling

1 INTRODUCTION

During last years the significant development of piezoelectric materials, especially multilayer ceramics [1], has been observed. These ceramics are sintered from a powder into practically any shape and may work as actuators with the theoretically atomic scale movement accuracy. Having in mind progressive development of microprocessors, which may control micro-actuators, the next technological revolution is very likely. Revolution, which would be based on micro-machines. It than creates a need for micro-products as parts for these machines. One should than foresee further and accelerated development of microforming also of nanomaterials [2]. Using the microforming technology it is theoretically possible to achieve atomic scale surface roughness and also sharp edges, which are very difficult to achieve using other technologies. Micro-blanking processes with different modifications seem to be especially promising [4]. In the micro-parts production micro-blanking processes might be used not only for punching holes, but also, or better to say, mainly to manufacture high accuracy and surface quality semi-products [5]. Such an approach defines subsequent differences between micro-blanking and "standard" blanking. Except of the commonly known scale effect [6], features like high shape accuracy (resulting in a small clearance) and high surface quality, often some special geometrical features occur. In the micro-blanking processes relative high product height (h) to diameter (d) factor might be expected, h/d = 0.6 – 0.8. All these conditions cause additional technological difficulties.

2 TOOLS DAMAGES IN INDUSTRIAL PROCESSES

Recently micro-blanking in the mass production mainly refers to manufacturing of electronic parts.. Multi-punches (even tens punches) tooling is used for manufacturing of these parts. Most often very dangerous damage relies on tearing off the end of the punch, Fig. 1a. A sequence of this process is shown in Fig. 1b,c,d. On the way down punch during indentation inside material exposes chemically and physically active internal layers. Most often first adhesive joins occur and in consequence first micro-pick-ups are created during these phase.

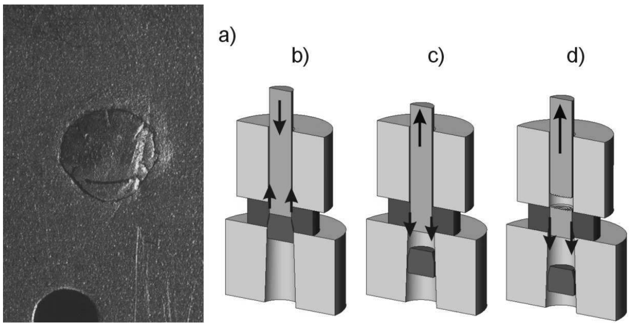

Fig. 1.Damage of the punch in micro-blanking of stainless steel 304, d=1 , d/h = 0.7:a) punch-end that remained in the strip; b), c), d) process phases (arrows show forces acting on the punch)

These might be torn off and pushed beyond the contact zone where are not dangerous anymore, Fig. 2. These might however remain on the side surface of punch and successively growing there during further blanking.

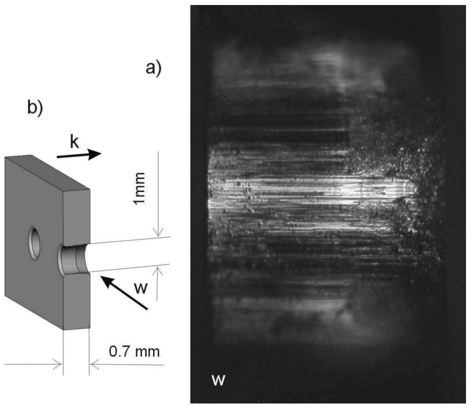

Fig. 2. *Pick-ups* remained on the internal surface of micro-blanked strip (a), b) specimen preparation method, w – picture direction

This phenomena is extremely disadvantageous because the pick-up material is very hard [7]. Finally, after certain number of strokes the adhesive join occurs on the large area of a free surface of the punch that leads to tear off its end, Fig. 1d.

3 GALLING TENDENCY EVALUATION

There are numerous parameters influencing adhesive joining and galling phenomena. In the proposed method it is suggested to use only two parameters. The first is the sliding distance S^D, the second is so called Contact Quality C^Q. Under this name one should understand all factors other than sliding distance. These factors influence adhesive joints in a positive or negative way. Following the presented concept, tendency to pick-ups formation at the certain point of the free surface of punch may be described as the function G_T (x) – Galling Tendency where x is the distance from the punch nose along the axis of punch. This function is a sum of accumulated sliding distances under different Contact Qualities. It means that for the n defined types of contact G_T (x) will follow the equation:

$$G_T(x)=S^D{}_1(x)\cdot C^Q{}_1+S^D{}_2(x)\cdot C^Q{}_2+\ldots+S^D{}_n(x)\cdot C^Q{}_n \quad (1)$$

In the easiest way, factors $C^Q{}_i$ might be taken as weights of sliding lengths. These weights characterize tendency for pick-ups formation for each type of contact. The number of addend in equation (1) depends on the required accuracy of consideration. However, it is not recommended to take too many of them since the idea of a ~~the~~ simple estimation of function G_T might be lost. The starting point for this function estimation is finding distributions of all sliding distances $S^D{}_i$ that means to find the Sliding Distances Distribution Graph – SDDG.

4 SLIDING DISTANCES DISTRIBUTION GRAPH

For a simple analysis of the micro-cutting process it is enough to recognize 4 types of contact.

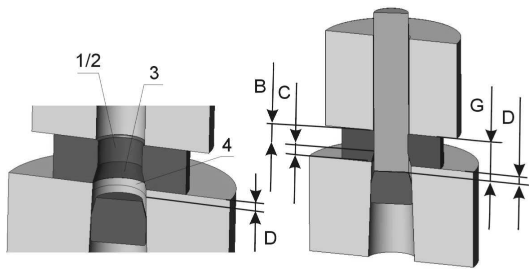

Fig. 3. Process characteristics – description in text

Types are as follows (Fig. 3): 1. contact during cutting (*cutting zone*); this occurs in zone 1, 2. contact with the same as in the point "1" surface, but after decomposition of material that diametrically changes contact conditions, now it is called *ductile zone* 2, 3. contact with *the fracture zone* – zone 3, 4. contact during punch indentation in the die – (*die zone*) zone 4. The lengths of each zone are defined using parameters shown in Fig. 3: B – length of cutting/ductile zone, C – length of the fracture zone, D – length of the die zone, strip thickness G = B+C. On the base of the already defined geometrical quantities B, C and D it is possible to build the SDDG that is shown in Fig.4.

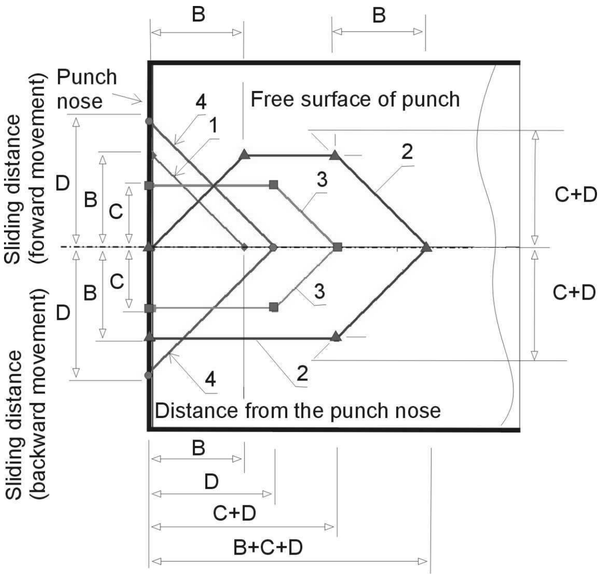

Fig. 4. The SDDG based on B, C, D; curves for 4 types of contact are shown: 1 – cutting zone, 2- ductile zone, 3 – fracture zone, 4 – die zone

The horizontal axis goes along the punch axis and represents the distance from the punch nose. The vertical axis touches the punch nose and represents sliding length. For better understanding, sliding distances curves for forward and backward movements of punch are drawn symmetrically to the horizontal axis. Both parts (above and below horizontal axis) of the SDDG represents positive value of sliding distances. This must be kept in mind during estimation of galling tendency function.

5 MICRO-BLANKING PROCESS

Micro-blanking of 0.7 mm thick stainless steel 304 strip (R_m = 1050 MPa) using the 1 mm punch diameter, 0.03 mm clearance and 100 MPa blank holder pressure was performed. After 120 strokes the end of one of punches torn off because of heavy galling on its free surface. Geometrical parameters for this process were as follows: B=0.5 mm. C=0.2 mm, D=0.1 mm. For the better understanding, the SDDG will be built in several steps. At the beginning punch is going into the strip to B=0.5 mm distance that means to the end of the cutting zone 1. The sliding length distribution on the free surface of punch along the punch axis is shown in Fig. 5a. The fracture occurs. Contact so far defined as cutting contact; type 1, changes into type 2. Punch goes further entrancing to the end of zone 3 that means progressive movement of C=0.2 mm.

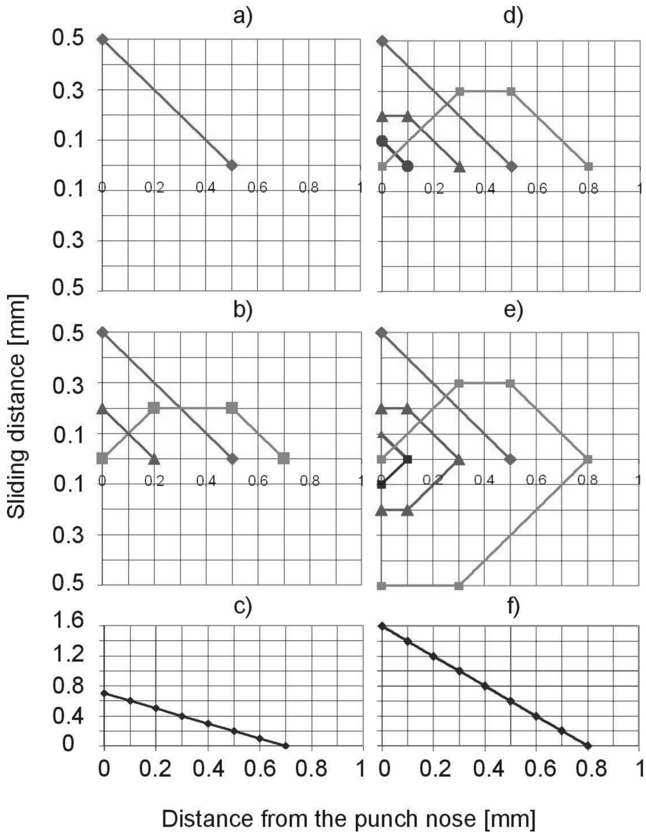

Fig. 5. Development of SDDG during micro-blanking

The consequence of it is supplementing the SDDG with two curves representing sliding contacts in zones 2 and 3, Fig. 5b. Adding now these three so far obtained curves one gets linear sliding distance distribution from 0.7 to 0 mm on the distance from the punch nose equal to 0.7 mm, Fig. 5.c. It is right because punch has moved along the distance B+C=0.7 mm. Punch is going now into the die zone, Fig.5d and than is going back all the way out that modified the SDDG to its final shape shown in Fig. 5e. The result of adding of all curves is shown in Fig.5f. Further blanking modifies the SDDG by multiplying only ordinates of each points of curves with the number of strokes. Based on the SDDG it is now possible to use the equation (1) to evaluate galling tendency function G_T. Certainly, the method and the quality of determination of factors C^Q_i is extremely important. In the present—paper this problem is not analysed in detail, since the goal is to present a method. The following factors have been taken: C^Q_1 = 0.6, C^Q_2 = 0.2, C^Q_3 =0.14 and C^Q_4 =0.06 (note that the sum is 1). They are not denominated quantities. It means that the galling tendency G_T refers to the equivalent sliding distance.

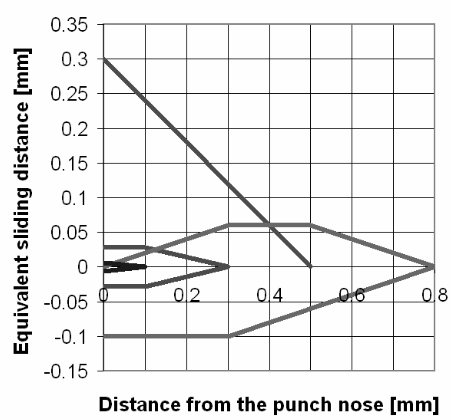

Fig. 6. Equivalent SDDG for one stroke

Proportion of C^Q_1 to C^Q_2 was evaluated based on FEM simulation. Remaining factors C^Q_3 and C^Q_4 have been arbitrarily chosen at this state of investigation.

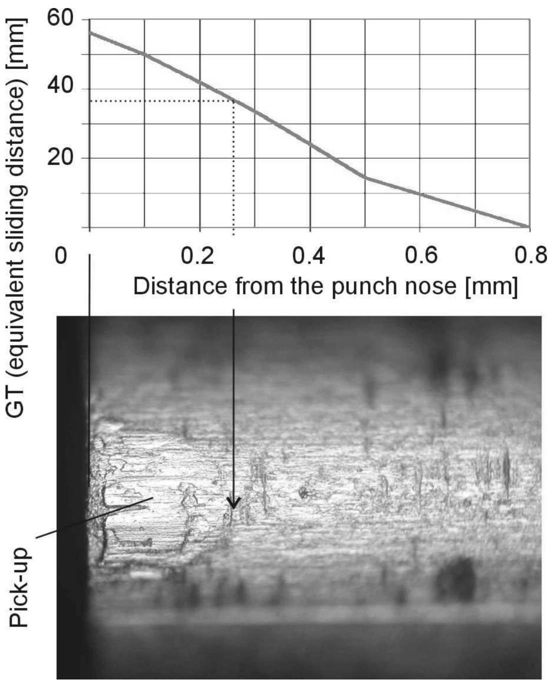

Fig. 7. Galling tendency distribution for 120 strokes and the corresponding punch picture – arrow shows the end of pick-up

It was only assumed, based on the experience that from the galling tendency point of view the zone 3 is more dangerous, than the zone 4. The equivalent SDDG for a single blanking is shown in Fig. 6. Based on this graph galling tendency distribution $G_T(x)$ after 120 strokes has been estimated. It is shown in the Fig. 7 together with the picture of punch surface that corresponds to the graph size. Based on this comparison the critical value of G_T can be found $G_{T(cr)} = 36.5$ mm. This value refers to the position of the end of the pick-up, which is shown in Fig.7 using the arrow.

6 CONCLUSIONS

1. The introduced method makes possible to determine function describing distribution of galling tendency on the free surface of punch along the punch axis; galling occurs when this function riches a critical value. The method introduces calculations based on geometrical process parameters and *contact quality factors* related to contact phenomena.
2. It would be profitable to undertake investigations leading to determination of the set of *contact quality factors* and to estimation of the critical value of galling tendency function.

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