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Research Article

INFLUENCE OF TOOL WEAR ON MATERIAL FLOW

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ABSTRACT

The cold bulk forming is a technology that is commonly used in many industrial enterprises. Even though nowadays high demands are posed on labour productivity, quality and own production costs, the findings from practice suggest that not sufficient attention is paid to the issue of tool management. Also, theoretical backgrounds and knowledge in this area are not processed in a sufficiently detailed and comprehensive way. This paper deals with the issue of prediction of the wear surface of the forming tools and their subsequent renewal. The research at selected materials was focused on the course of their straining in contact of the blank with the tool in the process of cold bulk forming. The experiments were based on a simple performance of the conventional upsetting test. On the basis of analysis of the results the mechanism of tool wear by abrasion was determined and its impact on the service life time of the tool and also the possibility of influencing the quality of final parts were evaluated.

Keywords: Bulk forming of metals, the tools, material wear, prediction.

INTRODUCTION

The global economy in recent years has been growing with unprecedented dynamism, which is associated with the development of existing and new technologies, with discoveries of new materials and machinery equipment. The companies in their efforts to maintain their leading positions and remain competitive, must constantly seek for new production opportunities and economical production methods with the contribution of new technologies. Due to rising prices of energy, materials and other costs associated with the production, the effort of a number of manufacturers to influence the tool life comes to the forefront, in order to extend the period of their use in the production process [1,2].

Both hot and cold bulk forming rank among the important technologies used in practice. During forming in the contact surfaces of the deformed materials and tools arises a series of dynamic processes of structural transformations [3, 4, 5].

The effect of time-varying forces of adhesion and pressure can lead to various forms of surface wear, which progresses from simple abrasion of particles up to the release of larger volumes depending on cumulation of cyclic elastic plastic deformation in the exposed layers. The abrasive and adhesive processes belong to the main mechanisms of tool wear. Abrasive wear can be assessed by the level of deformation or tension that lead to the irreversible changes. There are two principal planes in abrasion of surface layer, namely in contact between the tool and deformed material. The degree of qualitative degradation of the tool surface can be evaluated as an increase in surface roughness after repeated exposure. The second plane is then the growing change in dimension and shape of the functional surface of the tool, which is usually decisive for the check of well tried tolerances of the forming tool [6, 7, 8].

EXPERIMENTAL PART – THE COURSE AND EVALUATION

The main experimental measurements were focused on the monitoring and verification of the particular forming tool in forming process by

Fig. 1. Upsetting test configuration

means of the upsetting test. The upsetting is one of the basic operations of both the cold and hot bulk forming. The upsetting test was performed cold and without lubrication [9, 10].

A comparison was made in development of wear both at two types of material for forming tools, and at two materials of samples to be exposed to upsetting. Upsetting tools were designed as prismatic plates from tool steels X210Cr12 and 60WCrV7 in dimensions of 120x120 mm, including the adequate heat treatment (Fig.1). Marking the tool is shown in Table 1, and was supplemented by indices 1 and 2, for an easier identification of the tools within the experiment [9].

The samples exposed to upsetting were prepared from two steel alloys - S355J2G3 standard carbon steel and 16MnCr5 grade chromium manganese steel. The size and the marking are shown in the Table 2. The materials for samples were chosen based on the requirements given by material upsetting tests, in accordance with standard and was decided to use the carbon steel for ordinary forming and heat-treated steel suitable for forming more demanding shapes. This steel in its thermally unprocessed state has comparable mechanical properties.

Testing the samples was carried out on a hydraulic press for tensile and pressure mechanical tests, working with numerical control and data collection, with maximum load of 400 kN. The place of exposure was located into the centre of each plate. During the experiment, it was necessary to repeat the centering of tool against the machine. Evaluation and measuring of the profile of the exposed places of four mutual combinations of contact between the upsetting plate and material in forming process was carried out always after 10 cycles of upsetting test in the longitudinal and transverse axis of the formed calotte. The measurement was made with a touch probe, which was connected to a digital indicator (Fig. 2). On the plate of the forming tool the measured distance was marked, on which, data were gradually recorded on the thickness of the exposed layer, by every 10 pieces. On the surface of the tool in the point of contact between the sample exposed to upsetting and the tool occurred the gradual decrement of the material and creation of a calotte and partial adhesion of material particles on the side of the calotte and their subsequent tearing out, and gradual adhesion on the surface and alternating strenghtening of a given layer.

Table 1. Marking of tools

Marking of tools		
Set 1	Marking od plate	Material
Upper plate	19.733-1	60WCrV7 (1.2550, ČSN 41 9733)
Lower plate	19.436-1	X210Cr12 (1.2080, ČSN 41 9436)
Set 2		
Upper plate	19.733-2	60WCrV7 (1.2550, ČSN 41 9733)
Lower plate	19.436-2	X210Cr12 (1.2080, ČSN 41 9436)

Table 2. Material and marking of samples

Labeling of samples	Material	Dimension of sample		Number of pieces of samples [ks]
		Diameter [mm]	Length [mm]	
11 523	S355J2G3 (1.0570, ČSN 41 1523)	15	27	190
14 220	15MnCr5 (1.7131, ČSN 41 4220)	12	22	230

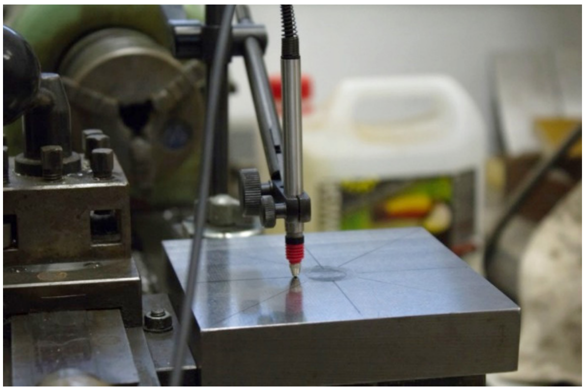

Fig. 2. Surface scanning by touch probe [6]

The arrangement of the experiment, regarding its layout, character and repeated handling, had to simulate conditions of accuracy during the gradual exposition of tools, which can be expected during normal operation of bulk forming [9].

The place of the highest mechanical stress was also evaluated by using a stereo microscope. It is obvious that the material wear and material decrements are not equal throughout the surface. It is caused by combination of materials for tools and samples with different degree of strenghtening (Fig. 3, Fig. 4).

The evaluation of the experiment was carried out for a mutual combination of two materials for a tool plate and two materials for the sample. Thus, four mutual combinations of materials were obtained (Fig. 5).

The dependence of the depth of wear on the number of pieces exposed to upsetting in all four mutual combinations is nonlinear and has a stepped character. At the beginning, the curve has a gradual polytropic character. At the moment of reaching the saturation degree, which corresponds to reaching the degree of cohesion, the release of larger amount of material from the surface occurs. A repeatable elastic cumulation of elastic plastic deformation in the contact layer of material happens, always after several tens of cycles. The response in surface layer is

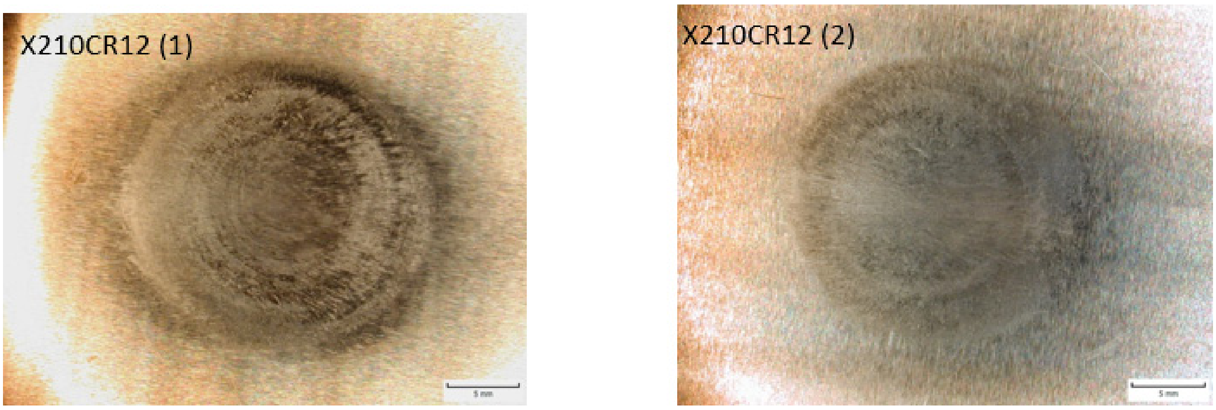

Fig. 3. Surface scanning by touch probe, a photograph from the stereo microscope of the place of mechanical stressing of tool material after upsetting of 190 pieces (3.5x enlargement)

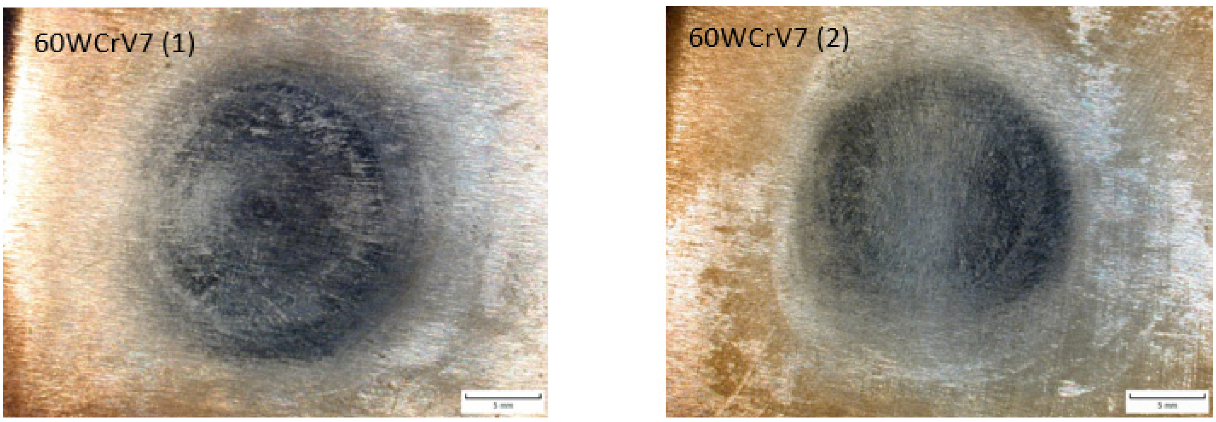

Fig. 4. Surface scanning by touch probe, a photograph from the stereo microscope of the place of mechanical stressing of tool material after upsetting of 190 pieces (3.5x enlargement)

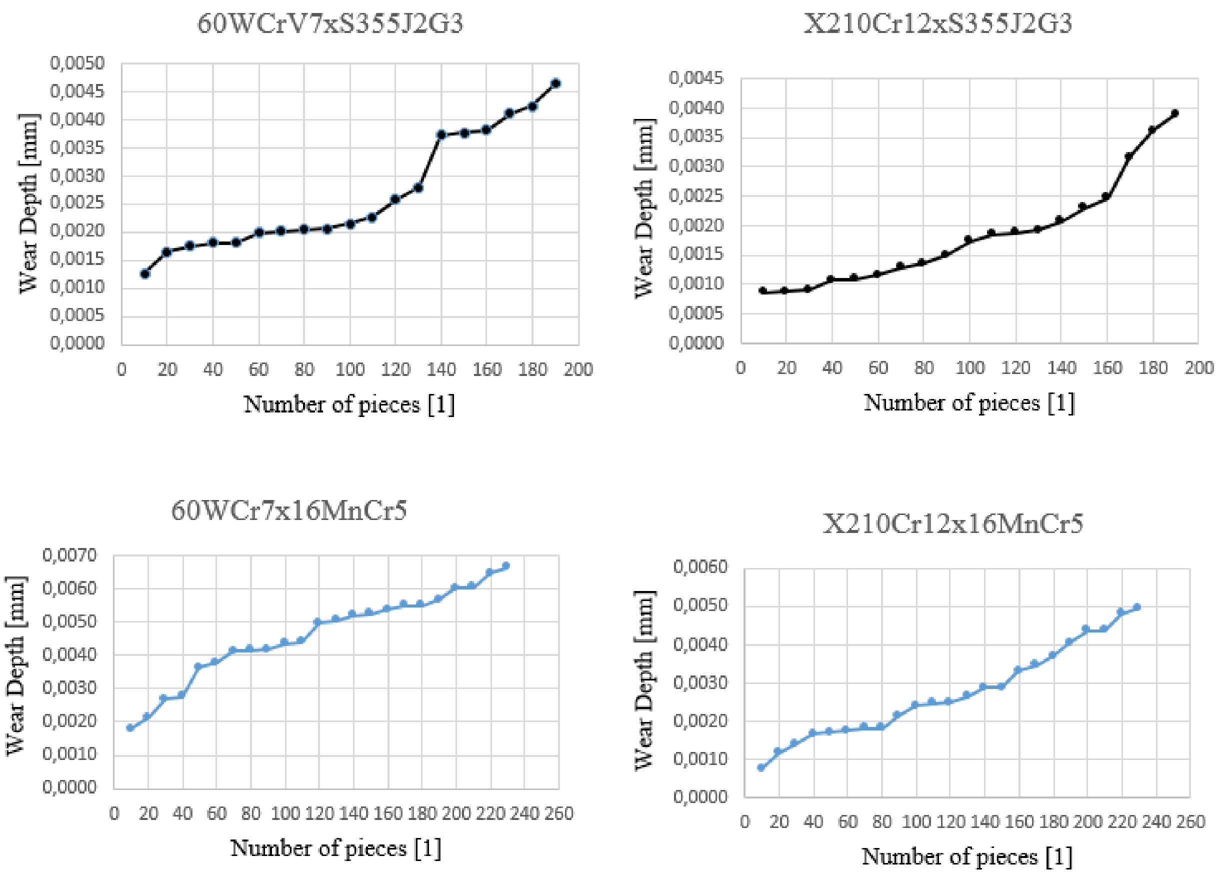

Fig. 5. Wear depth – all combination of the contact

the growth in strenghtening which is ended in a form of refraction of larger volumes of surfaces. During upsetting of both tool alloys the wear depth was achieved after 190 cycles in the range 4 μm for steel type X210Cr12l and 6 μm for steel type 60WCrV7. From the graphs it is obvious that a larger degree of wear of the tool surface occurs in case of steel type 60WCrV7 in contact with both deformed materials and also corresponds to distinctively lower mechanical properties of this steel.

RENEWAL THEORY

Renewal of forming tool can be done in several ways. The main factors influencing the decision on the renewal of the tool, or its renovation or purchase of a new tool are, first of all, influenced by the required quality of the finished product, degree of utilization of tools and economic costingness regarding their acquisition. The renewal includes the following options:

- the renewal or renovation of the worn parts of the tool,
- application of surface treatment – coatings,
- acquisition of a new tool.

The process of renewal or renovation involves mainly the possibility of regrinding the functional parts of the tool and methods of appropriate thermal treatment. The choice of appropriate repair also depends on the shape of the tool and on the applied temperatures of forming. The lifetime of tool is significantly influenced by its construction solution, material and heat treatment of its functional parts. The application of surface treatment is another suitable solution. Today a variety of surface treatments already exists that can significantly increase the tool life. It seems particularly appropriate to apply PVD coatings, nitridation and recently tested various ceramic coatings. The easiest option of an exchange is to replace the whole tool, but this can constitute relatively high expenses bound in the amount of warehouse stock. Therefore, it is necessary to continue experiments in order to determine the limit value of wear that will signalize the necessity to replace the tool. All these options must be verified through further exploration within the research of lifetime of forming tools and applied in practice.

CONCLUSIONS

This paper contributes to the extension of current knowledge in the field of prediction of tools service life in the technological flow. So it brings a scientific contribution in the field of bulk forming and establishing of a methodology for evaluating prediction of wear of forming tools caused by the mechanical fatigue, especially through abrasion. Knowledge gained while performing basic experiments can be used in operating conditions. In order to determine the consumption of instruments is appropriate to establish a standard for consumption of tools, e.g. on the basis on the analysis of statistical data, which should be monitored in all enterprises by relevant departments or workers. The given area refers mainly to the technical preparation of production, through a suitable design of tools, cost-effective manner of production and through determination of adequate operational and supervisory conditions, can significantly influence a longer life of forming tools, and thus guarntee more efficient use of financial resources of the enterprise.

Further development of research can be directed to monitoring certain types of lubricants in combination with standard coatings of tool materials, which should increase the lifetime of the forming tool. On the basis of the methodology used for evaluation of wear of forming tools it would be appropriate to monitor the decrements in wear and compare different types of coatings and compile a summary of the results that will be applicable in practice. Another direction should be research in the wear of the functional surfaces of tools during the hot forming.

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