ANNALS OF THE ORADEA UNIVERSITY
Fascicle of Management and Technological Engineering
ISSUE #1, MAY 2014, http://www.imtuoradea.ro/auo.fmte/

COMPARATIVE ANALYSIS OF INDENTATIONS FROM SPATIAL IMPACT WITH PLASTIC DEFORMATIONS

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Abstract— The paper presents a study on the shape and dimensions of plastic indents remnant after collision between a free falling ball and a disc in rotation motion about an vertical axis. There are analysed and compared the plastic indentations resulting for a range of disc's angular velocities. The real profile of the prints was obtained with a NANOFOCUS laser scanner. A general image of the indentation profiles is presented together with some parameters characteristic to the imprints geometry.

Keywords—spatial impact, plastic indentation, experimental profile, plastic deformation

I. INTRODUCTION

THE impact phenomenon is treated in a large number of monographs and papers from literature.

The importance given to collision phenomenon is correlated to the effects concerning the human body, from the less harmful consequences occurring in sportive gymnastics, [1], [2], to the dramatic ones happening during transport accidents. The devastating effect of impact phenomenon can also be proved by remaining that the operation of all firearms is based on impact phenomena, [3]. In general case, an impact phenomenon is characterised by the variation of kinematical and dynamical parameters of a system during a very short time period.

The extremely short time duration of this variations leads, according to dynamics fundamental theorems, [4], to the incidence in the system of particularly intense forces and torques despite the fact that, the inertial characteristics of the system could presents especially reduced values. But it would be incorrect to consider that impact presents only destructive effects in current activity.

The fact that through collision processes, under certain circumstances, between the colliding elements of a system an important energy transfer takes place, led from oldest times to the occurrence of tools-the first human tool was a stone, and machines working by shock, like hammer mills and punching machines based on by plastic deformation.

The study of impact phenomenon can be more or less complicated depending on the hypothesis accepted in modelling the phenomenon. Especially interesting is a paper of Wang and Mason, [5] who show that treating a plane impact with Coulomb friction using classical mechanics leads to the conclusion that solution obtained is inconsistent. However, modelling using specific methodology of impact mechanics, more precisely by means of plane of percussions, proposed by Routh, [6], proves that the problem has a solution well determined. Keller, [2], tried to extend to the three-dimensional domain the Routh's method but the procedure is particularly difficult to apply.

As often met in other engineering areas, in analysing a definite phenomenon, first a theoretical approach is made, the model becoming more complex as new hypothesis are accepted, and the increased difficulty of the model requiring more intricate mathematical skills and accessible to fewer users. In this case, more productive turns out to be considering the actual situation and a direct experimental approach. The results of experimental research are afterwards interpolated and, possibly, extrapolated for a wider range of situations. The late approaching manner is used in the present paper for the analysis of the shape of the plastic imprint remnant after the collision produced when a metallic ball falls onto a disc rotating around a vertical axis.

II. LABORATORY EXPERIMENTAL DEVICE

The collision effects produced by a metallic ball in free falling against the frontal surface of a rotating disc are studied. The conditions of plastic indentation incidence are proved by Johnson, [7], who shows that, for such an impact case, the plastic deformation happens if the height of ball launching is greater than

2÷3(mm). The ball is a bearing one, having d=19(mm) diameter and the disc is made of aluminium. This pair of materials was chosen with the aim that all the deformation energy should be transmitted to the aluminium.

The laboratory test rig is presented in Fig.1. It consists in an aluminium disc fixed on the shaft of a d.c. motor. The horizontality of the disc face is verified using a bearing ball placed on the impact surface. When the ball remains immobile, the deviation from horizontal plane is guaranteed. The impacting ball falls free from a launcher specially designed to ensure repeatability. A ball identical to the colliding one is suspended with a cord to identify the radius on the disc where the impact will happen. A non-contact tachometer is used to find the angular velocity of the disc.

Fig. 1. Experimental device: disc mounted on motor's shaft (left) and angular velocity measurement (right)

In Fig. 2 is presented the disc with two imprints resulted after the impact with a ball of diameter d=19(mm), denoted by 2 and a ball of diameter d=30(mm), unmarked. The presence of the last print is justified by the necessity of analysing if the imprint accepts a symmetry plane.

Fig. 2. Plastic imprints resulted from impact with two different size balls

To obtain a more closing answer to this question, a crown of plasticine was set on the disc surface and a ball was launched for a speed of revolution 4900 (rpm).

From Fig. 3 it can be observed that for a soft material, the impact indentation doesn't present a plane of symmetry.

Fig. 3. For a soft material the plastic indentation does not present a plane of symmetry

III. Analysis of Results

The post impact plastic indentations were analysed using a NANOFOCUS laser profilometer. The sample increment was 10(μm). The spatial image of the scanned imprint is presented in Fig. 4.

In order to establish the profile on the two-dimensional image from Fig. 5, the operator chooses a section for which the profile would be analysed.

The choice of the section should preferable be as close as possible to the theoretical central section of the imprint.

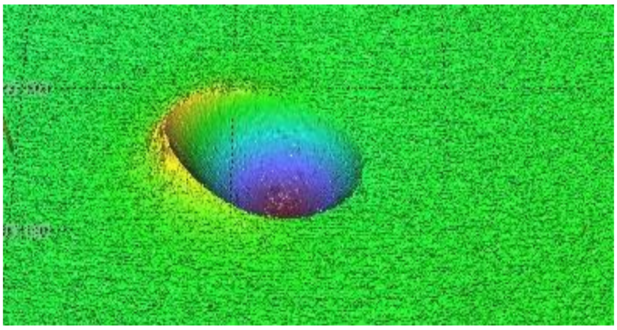

Fig. 4. Scanned plastic indentation

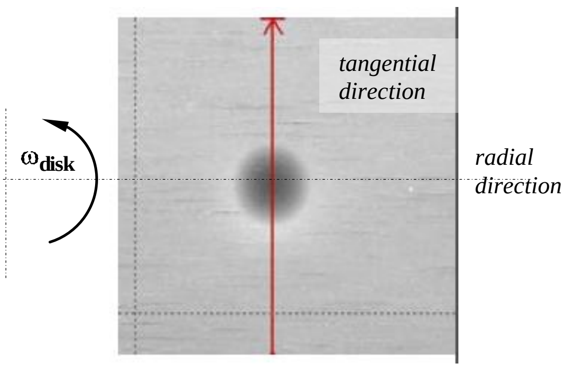

Fig. 5. Section selection for profile setting

The image for a profile is presented in Fig. 6.

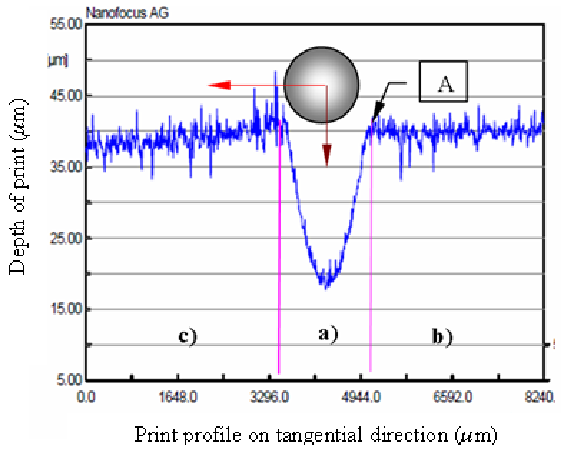

Fig. 6. Central print profile and characteristic regions

There are clearly observed three regions: a) the central region where direct contact with the ball happened; b) the region in rear of the ball, practically unaffected by impact; c) the region where the material is pushed and piled up subsequent to collision.

There were made five tests, the first with static disc and the next for the following rotation speeds: n={1050;1933;2980;4300}(rpm).

In order to perform a comparative study, the five profiles should be superposed. To overlap the images, an intrinsic element common to the graphs must be established. To this end, the point A was chosen. For precise finding of this point on the imprint's profile, the three mentioned zones were identified and n_1, n_2 are the indices of the points where the boundary between regions occurs, Fig. 6. The regions a) and c) were each one interpolated by parabola arcs and the b) region with a horizontal line, characteristic to non-deformed disc surface. At the parabolas intersection is the point B, the peak of the rim, and at the intersection between the contact region parabola and the horizontal line is the point A, Fig. 7.

For comparative reasons, the profiles corresponding to the five launchings were translated to have the same A point, Fig. 11. The profile identification in function of angular velocity is easy to make, taking into account the height of the ridge.

Figs. 8, 9 and 10 presents the dependency on disc velocity of ridge height, imprint's depth about the initial surface and length on tangential direction. All these parameters augment as the angular velocity increases.

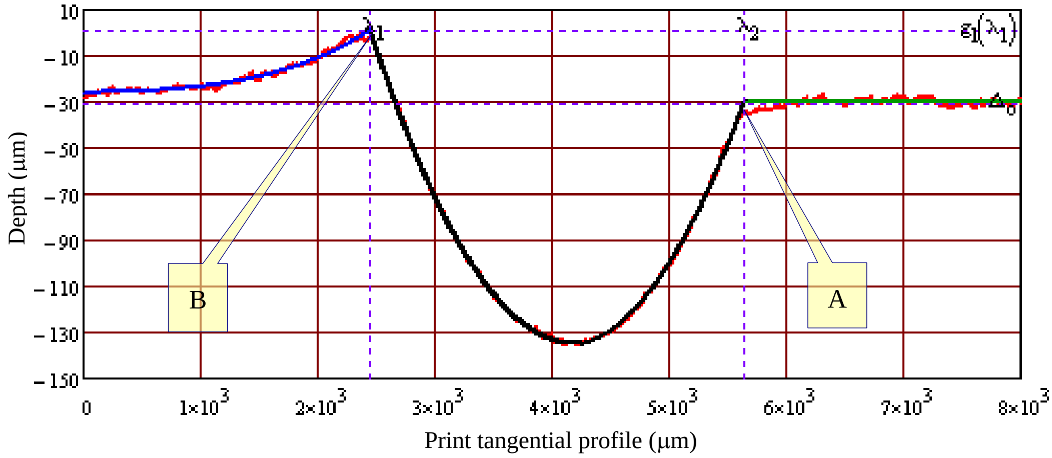

Fig. 7. Actual profile and interpolated regions, overlapped

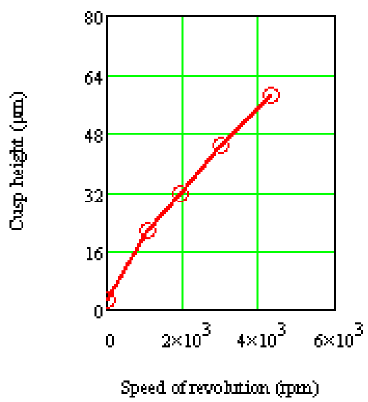

Fig. 8. Cusp height variation

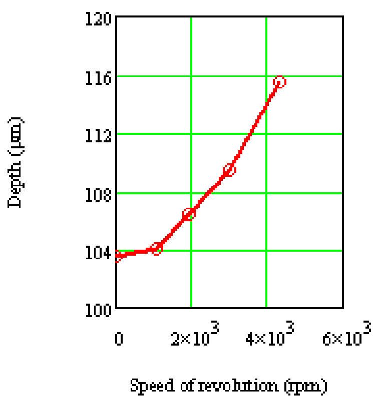

Fig. 9. Print depth variation

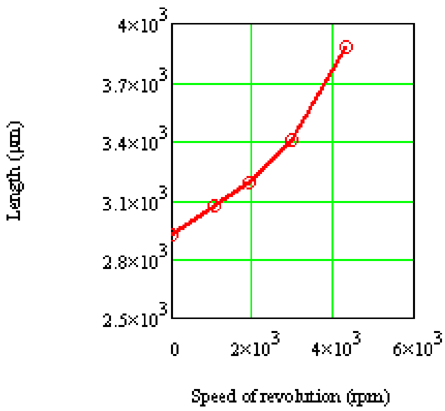

Fig. 10. Print length on tangential direction

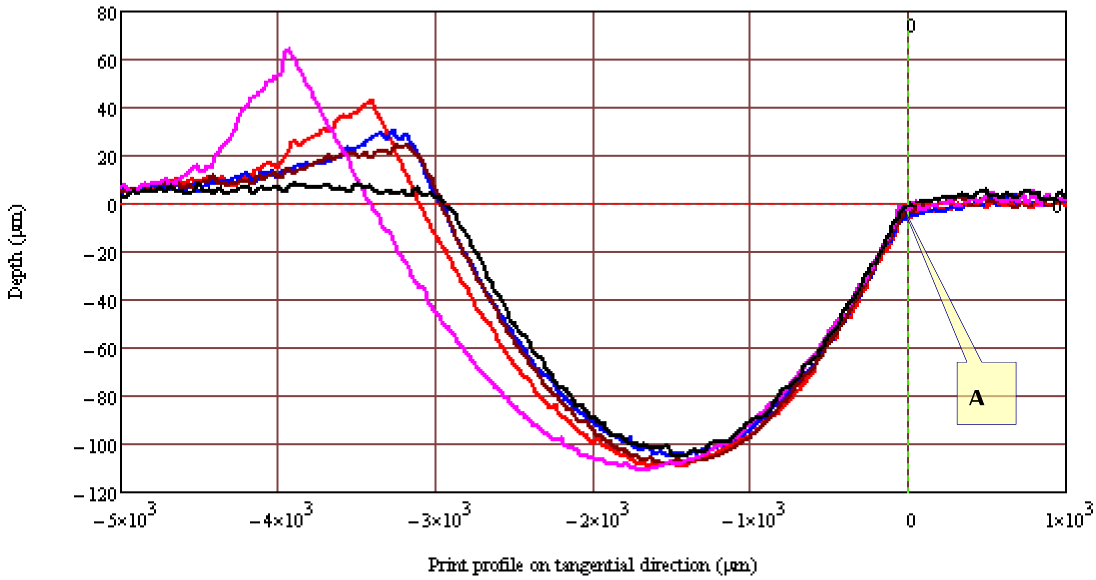

Fig. 11. Imprints profiles overlapped and translated for attaining a common point A

IV. Conclusions

In the paper there are analysed, using laser profilometry, the plastic imprints obtained after the collision of an aluminium disc rotating about a vertical axis with a bearing ball in free fall. During the tests data analysis, the necessity of a method for identification of print geometrical elements, applicable for any profile of plastic indentation, which reduces the degree of subjectivity, arose. The profiles in a central plane on tangential direction presents three regions: back impact zone, the actual impact region and a zone where a cusp appears as the material gathers in front of the ball, due to plastic state.

Initially, the points delimitating the three zones are difficult to estimate, but using the actual methodology, the final position of these points is practically independent on the initial choice, the procedure being based on an interpolation method that eliminates the rough errors. Thus, the paper presents a theoretical contribution besides the experimental method.

For a range of disc angular velocities, it was identified a point that can be considered common origin for all profiles. Translation of all profiles with the purpose that all these points to be brought in coincidence, allows the comparative estimation of their characteristics: ridge height, imprint depth and imprint tangential length. For these parameters there were found and plotted, quantitative dependencies on the disc angular velocity. For all the mentioned parameters is observed an increasing tendency with the disc’s speed augmentation.

The results of the work can be used in evaluation of surface characteristics in dynamic impact.

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