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NUMERICAL SIMULATION FOR POINT CONTACT QUASISTATIC PARAMETERS IN ELASTIC FIELD AND BRINELL TEST. SOME NUMERIC RESULTS

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ABSTRACT

This paper presents some computed results for point contat in elastic end plastic field. The compter model uses a linear dependence between load and relative approach in contact. The code uses a slice technique method. Usually the number of tranches to 1 mm of contact was chosen as rapport between ball diameters divided by 1000. It can be lower but for the graphical representation were choose that value. All results are compared with E10-Standard Test Mehod for Brinell hardness of Metalic Materials.

Keywords: *Herz contact, Brinell hardness.*

INTRODUCTION

Reference [1] presented a common method to compute the contact parameters in elastic point contact and Brinell contact. An attent analysis indicates a good correlation in the field of 100 HB to 500 HB, approximativelly 95% with the experiment [2]. For hardness between 500 HB and 800 HB, the correlation tendency forms 95% to 70 %, and that is not very precise if we intent to model the reality. A small adaptation was introduced and the precision between theory and experiment tends to 99%, in all field of Brinell hardness. The main change of the algorithm is the replacement of the fixed value of 13.5 with another one, between 13.2 to 9.5, as a function of hardness HB surface value.

The differences between this model and the tested values measured in [2] were presented. To show the stability of the process, the model is applied to an arbitrary point contact.

RESULTS FOR 13.5*HB

To show the algorithm precision when 13.5*HB is adopted as limit of the contact pressure for a Brinel Hardness between 100 HB and 800 HB, the plastic area are presented in Figures 1 to 8. In all these pictures, the black color represents the 13.5*HB value and correspond to the indentation area.

A ball of 10 mm is considered and an external force of 3000 kgf is used as the input data, according to [2].

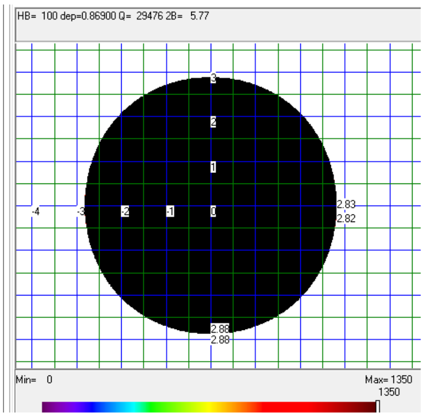

Fig. 1. Contact pressure and indentation area for 100 HB

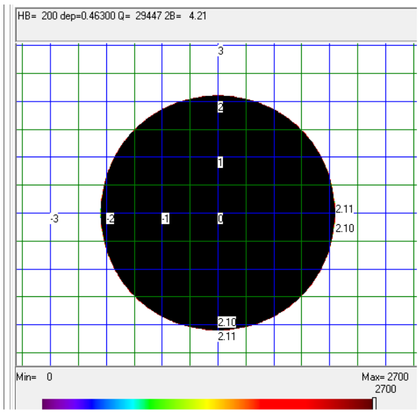

Fig. 2. Contact pressure and indentation area for 200 HB

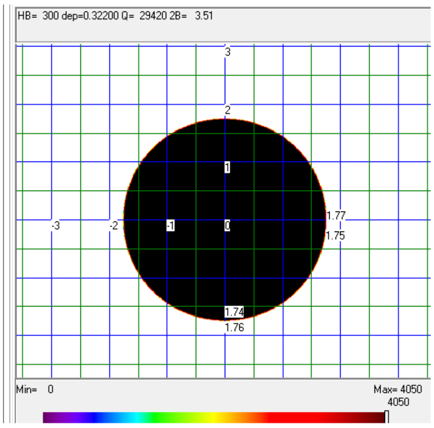

Fig. 3. Contact pressure and indentation area for 300 HB

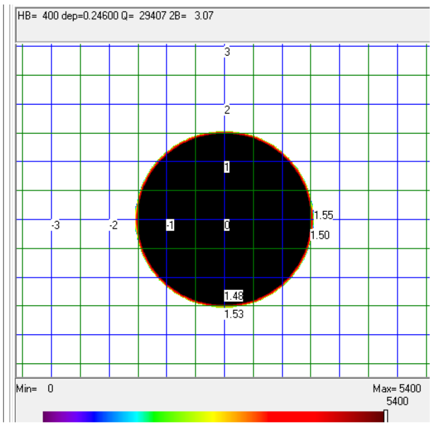

Fig. 4. Contact pressure and indentation area for 400 HB

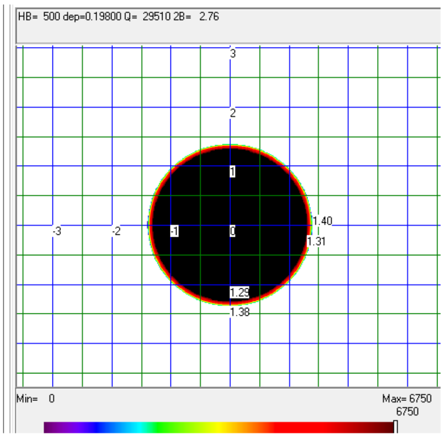

Fig. 5. Contact pressure and indentation area for 500 HB

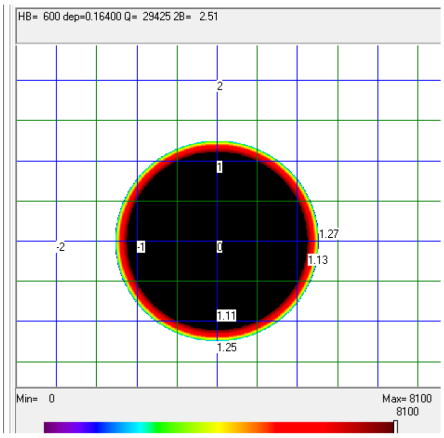

Fig. 6. Contact pressure and indentation area for 600 HB

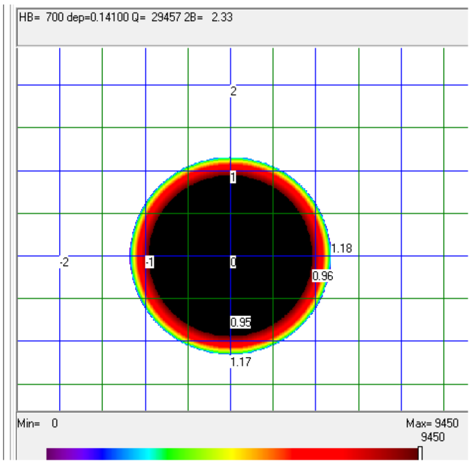

Fig. 7. Contact pressure and indentation area for 700 HB

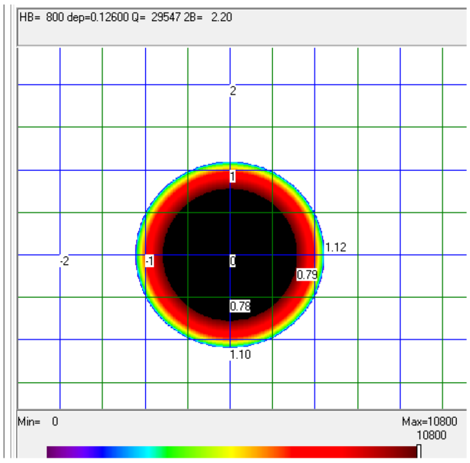

Fig. 8. Contact pressure and indentation area for 800 HB

As it is shown in the results from Figures 6, 7 and 8, the contact area evidences also a small region with elastic field. Graphically speaking, it results that are not complete black areas. Using as criteria the black color, the form the graph results have small differences between [2] and the computer simulation. The precision is presented in Fig. 9.

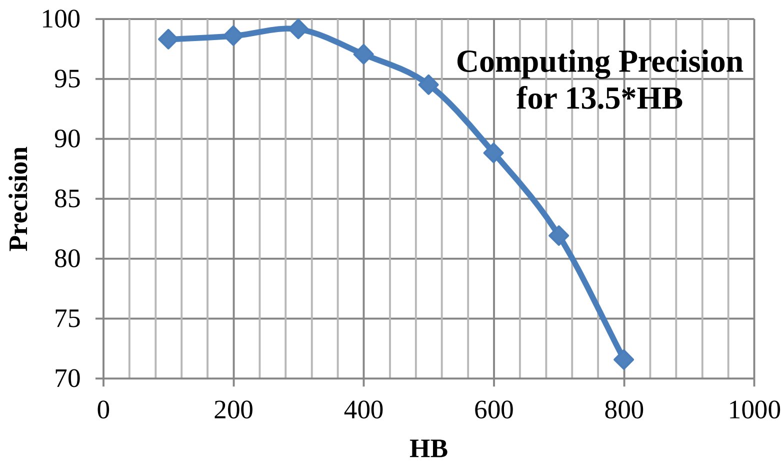

Fig. 9. Computing precision [1] versus the experiment [2], as a function of hardness HB

An careful analysis of Fig. 9 shows that a good validity of the algorithm presented in [1] that is a fit of 95% for the Brinell interval of 100 HB to 500 HB. For higher values, the 13.5* HB value produces a precision between 95% to 72%.

To be more precise, to obtain values close to 100 %, it is necessary to modify 13.5 constant with a variable named TV5, which depends on HB hardness. The function is presented in eq. (1), as follows:

$$TV5(HB) = (-0.01226 \cdot HB \cdot HB + 6.1148 \cdot HB + 12682)/1000 \quad (1)$$

The graphical representation of TV5(HB) function is given in Fig. 10.

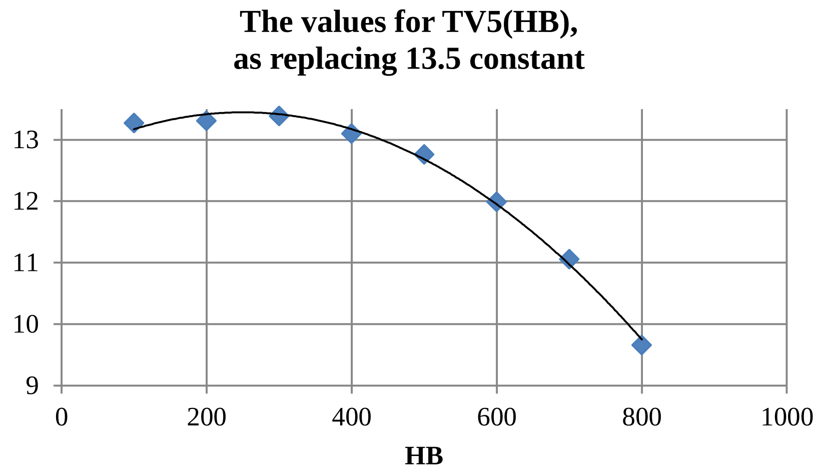

Fig. 10. TV5(HB) values used to replace 13.5 constant

It is shows that the values are close to the initial values of 13.5 in the interval 100 to 500 HB and have small values between 12 to 9.5 in the field of 500 to 800 HB. The influence of TV5(HB)*HB is presented in Figures 11 to 18.

RESULTS FOR TV5*HB

Note: black color represents TV5(HB)*HB and the indentation zone.

This analytical model considers that the ball has a higher hardness that that of the tested material and, whatever is the load, the ball is the elastic field; the only element that could be deformable in the plastic field is the plate, for which different values of hardness are considered. In Figures 11 and 12, a plate of low hardness is presented, taking into account a load of 29438 N, the contact pressure resulting as TV5(HB)*HB (black color) on approximately all the contact areas and at the exterior of this area, the elastic contur (other colors than balck) is practically impossible to be pointed out. Figures 13a...18a point out that, when applying the same load, the elastic contur may be evidenced, around the deformed zone.

In Figures 13b...18b, the load Q theoretically does not produce yet a point or a zone characterized by the pressure TV5(HB)*HB, only points of lower pressure being pointed out (here, other colors than black). All figures evidence the dimension of the contact zone (in mm), the value for valoarea HB the analysis is made for, the approach noted as dep, The contact load Q and the diemeter of the contact zone, noted 2B. The colored band under each plot is helpful for determining the correspondence between the contact pressure and its color two dimensions, expressed in mm, may be seen on the axes in Figures 13a...18a; the first number towards the origin expresses the limit of the plastic zone (field represented by the black color; between the first number and the second one (other color than black) there is a zone that behaves in an elastic manner. Due to the ellipticity of the contact, the values indicated on the horizontal axes and those on the vertical axes are slightly different, concretely, the ellipticity factor k is not 1.00, but ci 1.03, a value reflected on the dimensions of the contact semi-axes.

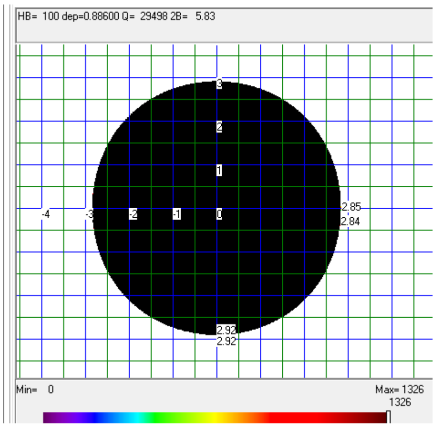

Fig.11. Contact pressure and indentation area for 100 HB

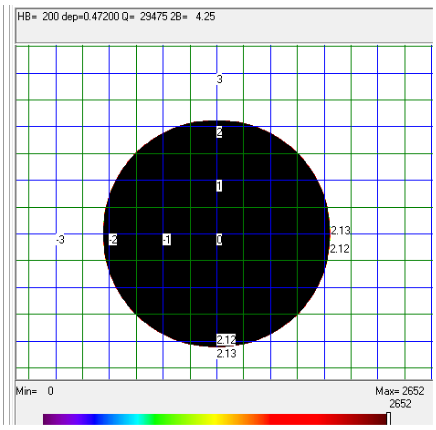

Fig. 12. Contact pressure and indentation area for 200 HB

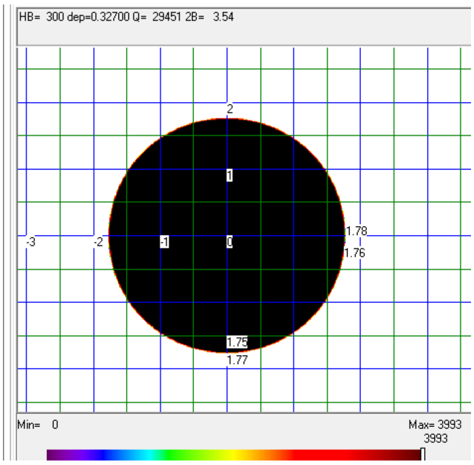

Fig. 13a. Contact pressure and indentation area for 300 HB and 3000 kgf

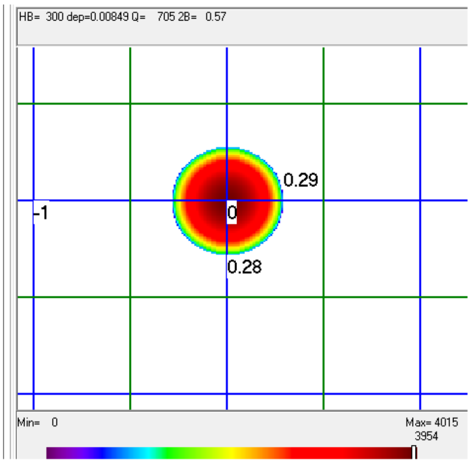

Fig. 13b. Contact pressure and no indentation area for 300 HB and 705 N

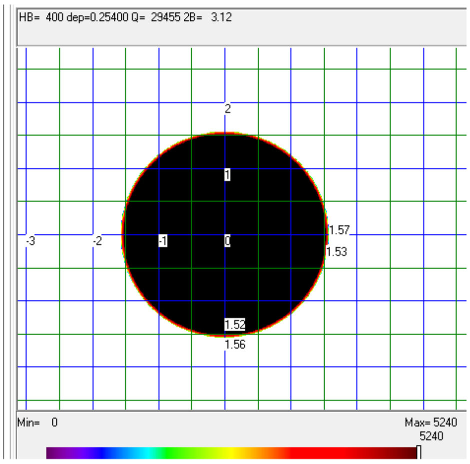

Fig. 14.a. Contact pressure and indentation area for 400 HB and 3000 kgf

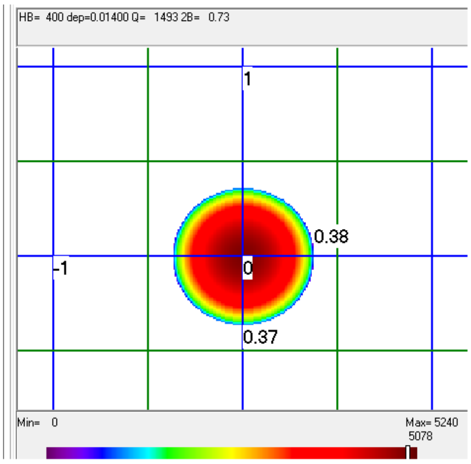

Fig. 14.b. Contact pressure and no indentation area for 400 HB and 1493 N

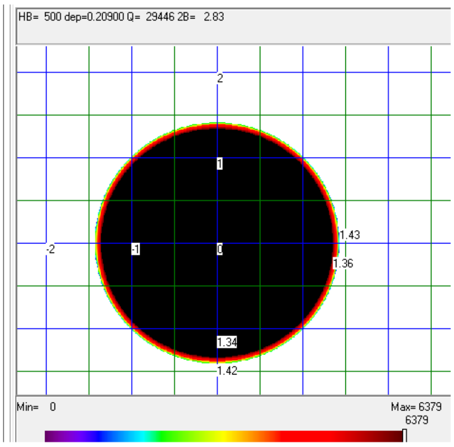

Fig. 15.a. Contact pressure and indentation area for 500 HB and 3000 kgf

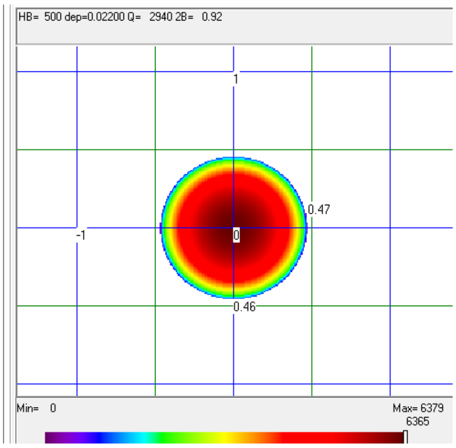

Fig. 15.b. Contact pressure and no indentation area for 500 HB and 2940 N

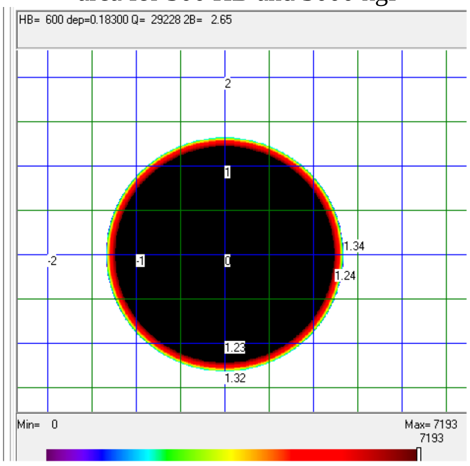

Fig.16.a. Contact pressure and indentation area for 600 HB and 3000 kgf

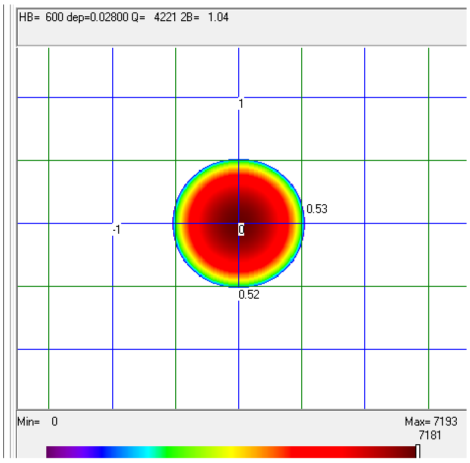

Fig.16.b. Contact pressure and no indentation area for 600 HB and 4221 N

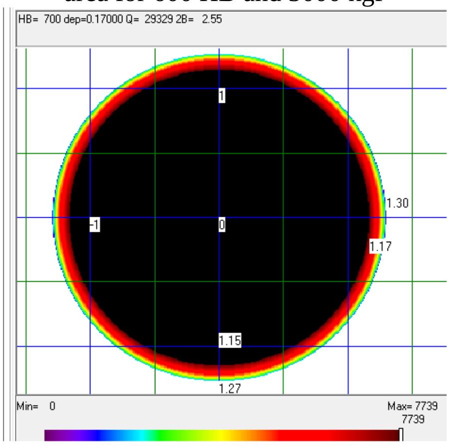

Fig. 17.a. Contact pressure and indentation area for 700 HB and 3000 kgf

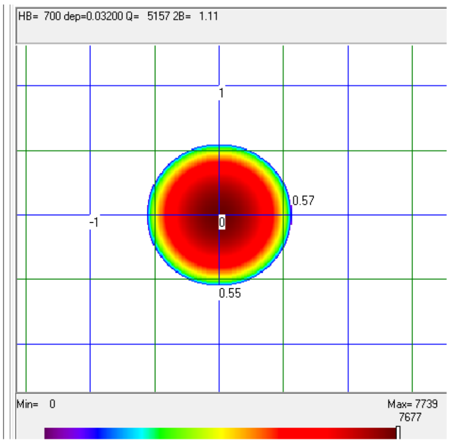

Fig. 17.b. Contact pressure and no indentation area for 700 HB and 5157 N

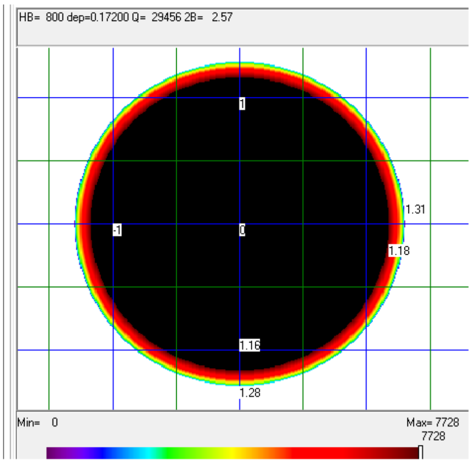

Fig. 18.a. Contact pressure and indentation area for 800 HB and 3000 kgf

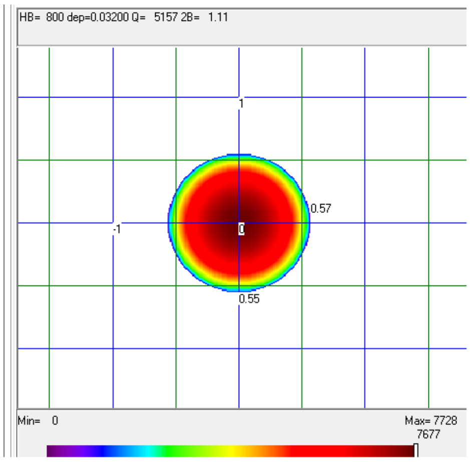

Fig. 18.b. Contact pressure and no indentation area for 800 HB and 5157 N

In this case, the precision of the algorithm form given in [1], corrected with TV5(HB), versus [2], is presented in Fig. 19.

Analizing the data in Figures 11, 12 and 13a... 18a, following dimensions of the limits characterizing the plastically deformed zones result:

for 100 HB: 2.92*2 mm=5.83, but in [2] the value 5.87 is given,
for 200 HB: 2.13*2 mm=4.26 in timp ce in [2] the value 4.26 is given,
for 300 HB: 1.75*2 mm=3.50, but in [2] the value 3.51 is given,
for 400 HB: 1.52*2 mm=3.04, but in [2] the value 3.05 is given,
for 500 HB: 1.35*2 mm=2.70, but in [2] the value 2.74 is given,
for 600 HB: 1.23*2 mm=2.46, but in [2] the value 2.50 is given,
for 700 HB: 1.15*2 mm=2.30, but in[2] the value 2.32 is given,
for 800 HB: 1.16*2 mm=2.32, but in[2] este indicat 2.17 is given.

Figure 19 graphically presents, for each considered value of HB hardness, the ratio between the minimum and maximum values indicated in [2] and those calculated (corresponding to the black field), multiplied by 100, for expressing as percentage the calculus accuracy. The calculated data, as obtained by the proposed mathematical model is close to the experimental data given in [2].

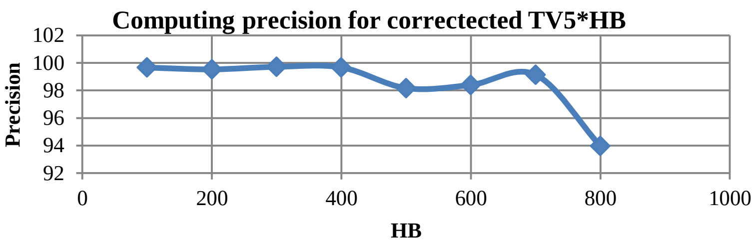

Fig. 19. Computer simulation [1] versus experiment [2]

Exemples:
for 100 HB, it results 5.83*100/5.87=99 %,
for 200 HB, it results 4.26*100/4.26=100 %,
for 300 HB, it results 3.50*100/3.51=99 %,
for 400 HB, it results 3.04*100/3.05=99 %,

for 500 HB, it results 2.70*100/2.74=98 %,
for 600 HB, it results 2.46*100/2.50=98 %,
for 700 HB, it results 2.30*100/2.32=99 %,
for 800 HB, it results 2.17*100/2.32=93 %.

From Figure 19, it results a good correlation between computer model and the model in [2]. The precision is 99% for HB values between 100 HB and 700 HB. If the hardness is 800 HB, for example, then the precision decreases to 94 %.

Of course, if the number of slices is increased, then the precision can be increased. Also, 100 slices for 1 mm is a reasonable number from the point of view of computer efficiency and also for engineering simulation.

EXAMPLE OF RESULTS FOR A RANDOM GEOMETRY

To exemplify, a model of a ball having a diameter of 20 mm, with a conformance of 0.52 and a middle diameter of 1000 mm was chosen. In this case, a hardness of 700HB is considered. For different external loads, the contact parameters were presented in Figures 20, 21 and 22.

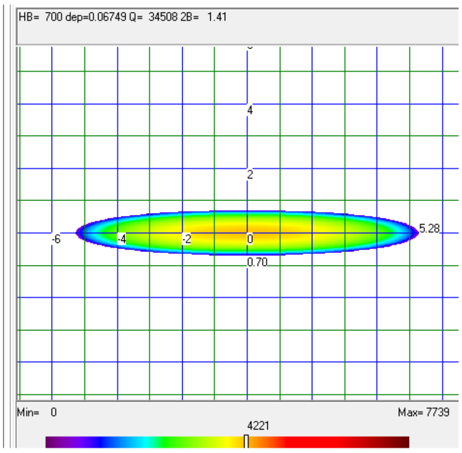

Fig. 20. Contact parameters for external load Q=34508 N

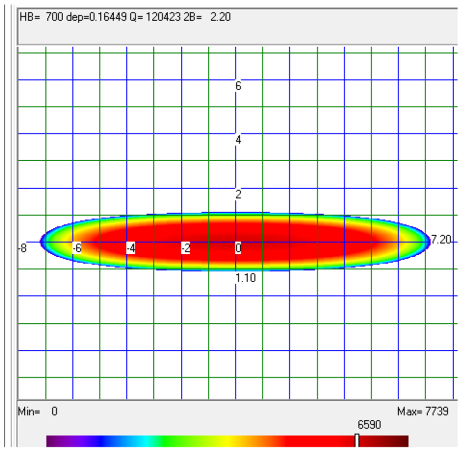

Fig. 21. Contact parameters for external load Q=120423 N

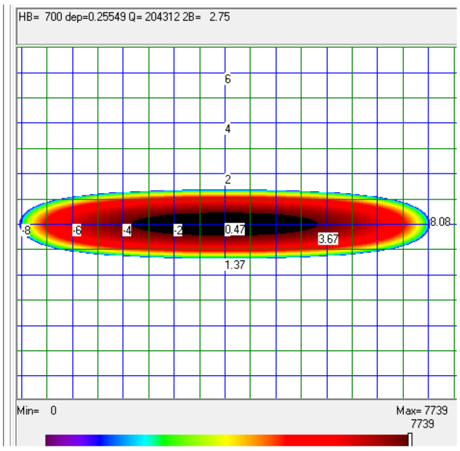

Fig. 22. Contact parameters for external load Q=204312 N (with indentation area – black color)

CONCLUSION

A good correlation between the mathematical model and reality is observed. The mathematical model presents in [1], corrected with the TV5 factor respects Hertz theory and takes into account the Brinell hardness of the material.

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[2] *** Standard Test Method for Brinell Hardness of Metallic Materials, American Association State Highway and Transportation Officials Standard AASHTO No. T70–86, E 10 – 01, June 2004.