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# Effect of geometry on the plastic contact between two hemispheres

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**ABSTRACT** – Mechanics of plastic contact is very important for determining the (micro-) geometrical change of contacting surfaces. This paper proposes a finite element analysis for the plastic contact between two deformable hemispheres. The effect of geometry on the degree of plasticity was presented.

## 1. INTRODUCTION

The theory on contact mechanics has been widely discussed in several studies. The elastic contact theoryof Hertz [1] is one of the underlying theories until to date. Greenwood and Williamson [2] have introduced a theory of elastic contact on rough surfaces in 1966. Chang, Etsion and Bogy [3] developed a model of elastic-plastic contact in for two regimes, i.e. elastic contact and plastic contact in 1987. In the model of [3] there is no transition regime from elastic to plastic contact behaviour, therefore Zhao, Maietta and Chang [4] in 2000 developed the elastic-plastic contact analytically for the three regimes, elastic contact, elasto-plastic contact and fully plastic contact. In 2002, Kogut and Etsion [5] also proposed an elasto-plastic contact analysis using the finite element method. Jamari and Schipper [6] in 2006 extended the elastic-plastic contact situation in a more general form that can be applied to ellipsoids in contact.

Study of the contact's degree of plasticity is very important because it will determine the geometrical change of the contacting surfaces. Johnson and Shercliff [7] in their hypothesis say that when two contacting asperities have the same hardness, the depth of plastic deformation is expected to be the same for each body, independent of the geometries used. Based on this hypothesis Jamari [8] performed experiments by contacting two spheres (steel balls) and varying the radii of the spheres. The experimental results are in contrast to the hypothesis of Johnson and Shercliff [7]. The experiments showed that the plastic deformation is affected by the geometry of the contacting spheres. Hardjuno [9] in 2010 conducted similar experiments by contacting two hemispheres. The experimental results of Hardjuno [9] showed the same phenomena as found by Jamari, i.e. that plastic deformation depends on the geometry of the contacting bodies.

This paper presents the finite element analysis of the plastic contact between two hemispheres. The effect of geometry is represented by varying the radii of the hemispheres. The simulation results are compared with the experimental results of Hardjuno [9].

## 2. METHOD

A commercial finite element analysis software package Abaqus was used to study the plastic contact between two deformable hemispheres and varying the radii of the contacting hemispheres. Both of the deformable hemispheres were modeled by a quarter shown in Figure 1 due to its axisymmetry properties.

Figure 1 shows the boundary conditions of the contact system and its method for measuring the plastic deformation. Nodes which are located on the *x*-axis can only move in the direction of the *x*-axis while the nodes on the axis of symmetryof the hemispheres (*y*-axis) can move in the direction of the *y*-axis only.

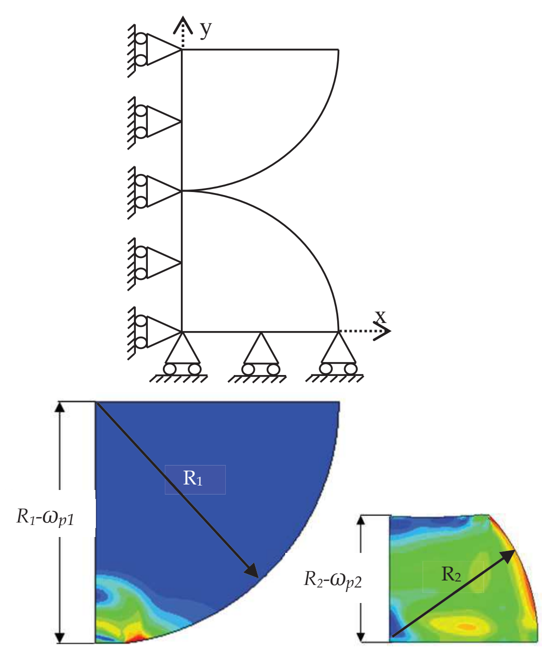


Figure 1 Boundary condition for modeling the contact between two deformable hemispheres and its method for measuring the plastic deformation.

The material behavior used for the model is elastic perfectly plastic with the modulus of elasticity of 96 GPa. The yield strength is 310 MPa and the Poisson's ratio is 0.34. The reference radius $R_1$ is 17.5 mm and the radius of the counter body $R_2$ is varied so that $R_1/R_2 = 1$, 2, 3, 4, 5, 6 and 7. Two loads of 8000 N and 11000 N with friction were simulated.

## 3. RESULTS AND DISCUSSION

Figure 2 and 3 show the results of the finite element analysis and is compared with the experimental results of [9] for the applied load of 8000 N and 9000 N, respectively. The ratio of the plastic deformation, after the load is removed (unloading), for the hemispheres, $\omega_{p1}/\omega_{p2}$, are plotted as a function of$R_1/R_2$.

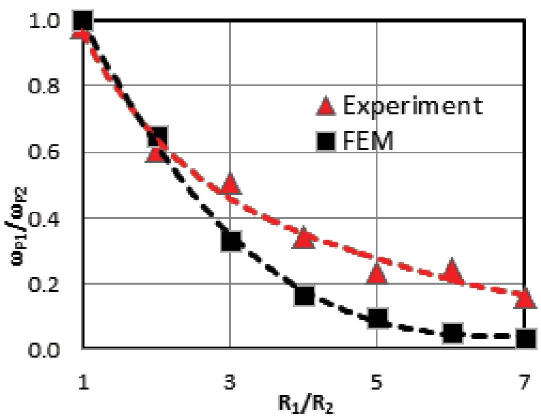


Figure 2 Ratio of the plastic deformation $\omega_{P1}/\omega_{P2}$ as a function of the ratio of the hemispheres radii$R_1/R_2$ for 8000 N load and a coefficient of friction of 0.1 (model and experiment).

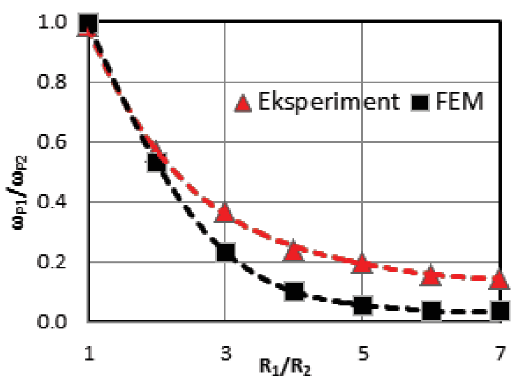


Figure 3 Ratio of the plastic deformation $\omega_{P1}/\omega_{P2}$ as a function of the ratio of the hemispheres radii$R_1/R_2$ for 11000 N load and a coefficient of friction of 0.1 (model and experiment).

It can be seen that the ratio of the plastic deformation decreases as the ratio of the hemispheres radii increases. In other words, the larger sphere show less plastic deformation compared to the smaller sphere. These results are not in line with the hypothesis of Johnson and Shercliff [7] for both the finite element analysis and the experimental results.

In both Figure 2 and 3, the results of the finite element simulation were achieved by using a coefficient of friction of 0.1. In fact, the experiments were performed under dry contact conditions. The deviation between the finite element model and the experiments increases as the ratio of the radii increases. This may be caused by the difference in coefficient of friction for each contact system. For a high radii ratio the displacements of the deforming bodies is relatively higher for the smaller body.

## 4. CONCLUSION

The effect of geometry of the plastic contact between two deformable hemispheres has been studied by finite element analysis. Results show that the degree of plasticity is affected by the geometry of the contacting bodies. The ratio of plastic deformation decreases as the ratio of the hemispheres radii increases. The finite element analysis agrees with the experimental results.

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