Numerical modelling of mechanical contact between dissimilar materials

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Abstract. Since the beginning of the last century, the mechanical contact has been studied by many researchers who could find some relations between the contact area and other factors like contact load. One of these researchers was Hertz whose investigations about mechanical contact between cylindrical solid bodies has been used since that time. It is well known that the most real results are results of experimental tests. However, in this case, the experimental tests have some inconvenients to be solved, one of these, is the incapability of determine the contact area or the contact pressure distribution. Some investigators have employed different devices in order to solve the problems mentioned before. Since the 2000 year some researchers have employed softwares with Finite Element Method, this method has shown to be a practical tool in the understanding of behaviour of the bodies under contact conditions. In this work the authors present analytical and numerical results of two bodies in contact. This contact involves two main parameters, one is the geometry of the bodies and the other is the composition of them. The results show a very good correspondence between the numerical and analytical results.

1. Introduction

The mechanics of contact can define this concept because of the effect of surfaces of two bodies in touch due to the effect of an extern agent, this agent can be a pressure [1]. The mechanics of contact defines two main manners of contact; the first involves the geometry of the bodies in contact, these ones can be conformal and non-conformal. The conformal contact is generated when the bodies in contact have the same geometrical form, as an example can be mentioned the studies made by Hertz with two cylinders in contact. The non-conformal contact is generated with two bodies with different geometrical form, as an example, there is a disc in contact with a plane [2]. The second is based on the composition of the bodies in contact; these ones can be similar and dissimilar, similar refers to the fact that the bodies in contact are composed from the same material, dissimilar occurs when the properties of the materials which composed the bodies are different [3].

There are a lot of mechanical components that are in contact, mainly, in transmission systems. In this topic there are some factors to control in experimental tests, like temperature, surface treatment and roughness, wet, accuracy of the instruments and others more. Some investigators have developed different devices in order to predict the behavior of the bodies under contact conditions, these devices present an inconvenient due to the contact, only occurs when two areas are in touch, this makes to
predict difficulty the contact area and the contact stress distribution. Since the last decade some researchers have employed many softwares which are assisted by numerical tools. Their results have shown that these softwares can help the investigator to understand and predict the behavior of bodies in contact. In this work the authors present the results of a comparison between analytical and numerical results employing a software (Ansys) which is assisted by a Finite Element Method.

2. Analytical and numerical analysis
This work is composed by two parts, the analytical and numerical analysis. And the third part which consists in the comparison between the results from the numerical and analytical analysis.

2.1. Analytical analysis
The first part is to identify the kind of contact and the equations that will be required. The main equation is developed by Hertz [3]:

\[ p(x) = p_0 \sqrt{1 - \left( \frac{x}{a} \right)^2} \tag{1} \]

Where \( p_0 \) is the peak pressure and \( x \) is the position in the limits between 0 and \( a \).

\[ A = 2 \left\{ \frac{1 - \nu_1^2}{E_1} + \frac{1 - \nu_2^2}{E_2} \right\} \tag{2} \]

\( A \) is the relation between material properties of the bodies, \( E \) is Young’s modulus, \( \nu \) is the Poisson ratio and \( k \) is the conformal relation. \( P \) is the contact load and \( a \) contact width.

\[ k = \frac{1}{R_1} + \frac{1}{R_2} \tag{3} \]

\[ a^2 = \frac{2PA}{\pi k} \tag{4} \]

The next part shows the properties of the materials of two bodies [4] and [5]:

| Table 1.- Properties of materials. |
|-------------------------------------|
| Material               | Steel SAE 1020 | Aluminum 6061 |
| Friction coefficient | 0.55-0.68 | 0.47-0.6 |  |
| Young’s modulus        | 207 GPa | 70 GPa |
| Poisson                | 0.3 | 0.33 |

The dimension of the specimen is a ratio of 5 millimeters with 10 millimeters of width. The ratio corresponds to the soft material, in this case, Aluminum 1060, and the plane to Steel SAE1020. The \( P \) value will be between 100 to 1000 Newton.

2.2.- Numerical analysis.
The first part is to create the model with a controlled manner, and choose the element in three-dimensional solid, in this part is important to stablish the dimensions of the bodies (figure 1). Create two solid bodies and stablish the necessary conditions for a contact analysis [6]. On the second part is necessary to assign the material properties to the correct body, this is important to do before the meshing process [7]. The mesh part must be done in a controlled manner to create quadratic elements. In this part it’s important to analyze carefully on the curved body. This must have similar form (figure 2).
The next part is to establish the necessary boundary conditions for the analysis [7]. It must be employed the elements Conta and target. The first one for the body which will be pressuring against the plate and the second for the body which will be static. These elements will appear in other colors (Figure 3).
3. Results
In this part the authors compare the numerical and analytical results. The most important part is the distribution of the contact pressure and the capability of observing the behavior of the bodies under contact conditions.

3.1. Numerical results

Figure 4. Stress distribution on the Y axes, $\frac{N}{mm^2}$.

Figure 5. Shear Stress distribution $XY$, $\frac{N}{mm^2}$.
3.2. Comparison between numerical and analytical results.
This part corresponds to a comparison between numerical and analytical results.

Figure 6. Contact pressure distribution, $\frac{N}{mm^2}$.

Figure 7. Pressure contact (peak), Color blue corresponds to analytical results and orange color to numerical results, $\frac{N}{mm^2}$.
4. Conclusions
The numerical results show a very good correspondence with the analytical results. This can be used with the purpose of get a better understanding of the mechanical contact and all that it involves. The results show a difference not greater than the 5 percent. The most important part are the figures which show the behavior of the shear and normal stresses of the bodies in contact, and these ones correspond with the literature. In the figure 4 the distribution of the contact stresses show the major stresses at the center of the contact in compression, and tension near the boundaries, this behavior is very difficult to predict and watch in experimental way. All mentioned before, propitiate the use of softwares with Finite element Method as a tool to understand about all kinds of phenomena which present in the Mechanics, in addition to taking less time than the experimental manner to solve the problem.

5. References
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