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# Effect of Contact Force Between Rough Surfaces on Real Contact Area and Electrical Contact Resistance

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## Abstract

Until nowadays, surface roughness effects were ignored in the analysis, due to the difficulty to generate a rough surface model and also to simplify the model in order to reduce calculation time. However, many engineering fields, such as MEMS, seek to improve the behaviour of the system at the surface level or the interface between surfaces. Thus, with the advance of numerical capabilities, the topography of the surface can be included in finite element simulations.

This paper presents two methods for generating rough surfaces, one using the real shape with an original reverse engineering method and the other one by using a parametric design language to generate a normally distributed rough surface.

As an application to demonstrate the power of these methods, we choose to predict by simulation the electrical contact resistance and the real contact area between rough surfaces as a function of the contact force. This application is a major concern in RF MEMS ohmic Switches and shows an original approach to extract a guideline in choosing a design, materials and process flow to minimize the contact resistance.

The agreement between the numerical model and an analytical model is very good and validates this novel numeric approach.

## 1. Rough surface generation procedure

A variety of methods to generate rough surfaces in finite element models have been proposed. But all of these methods deal with a statistical or fractal description of the surface's roughness. The originality of this work relies on a novel approach using a reverse engineering method to generate the real shape of the surface. For this purpose, we used an optical profilometer (VEECO) to capture data of the surface's points in 3D of an electroplated gold surface. Then, treating the data file using Matlab functions, we convert the closed surface from a stereolithography format to an ASCII file compatible with ANSYS Parametric Design Language (APDL). In the final step, the rough surface was obtained by creating key points using data from the imported file. Since the key points are not co-planar, ANSYS uses "coons patches" to generate the surface then we used a bottom up solid modelling to create the volume with the rough surface on the top (Table 1 described the full method).

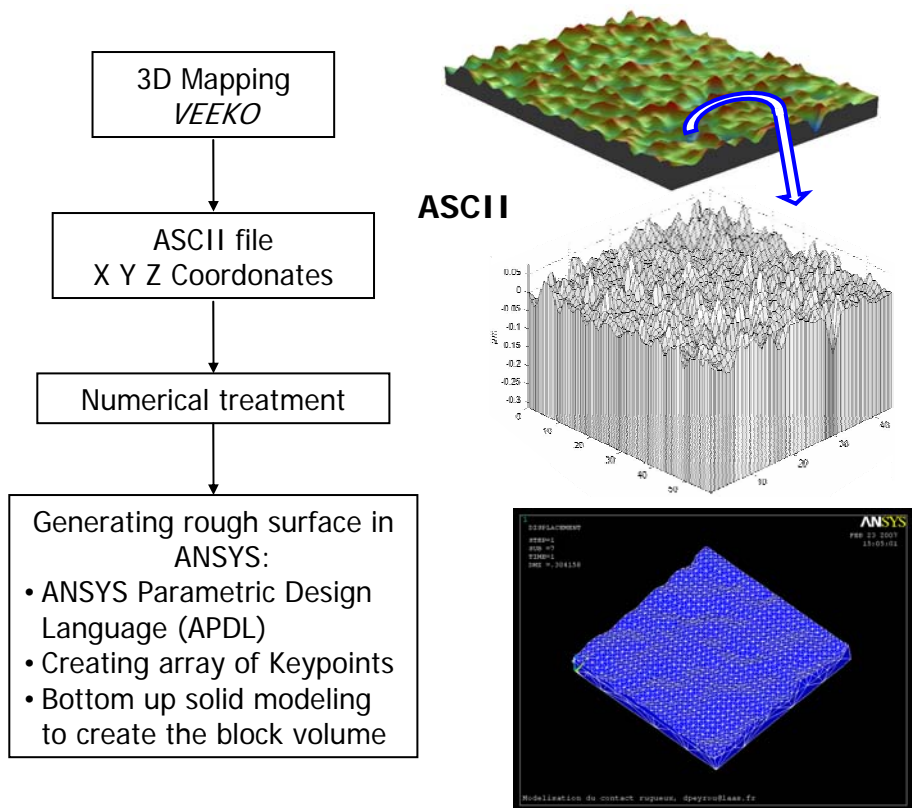


Table 1 Reverse engineering method

The second method, which is not described in this abstract, uses the APDL functions such as Gaussian DIStribution (GDIS) to generate a simplified rough surface by creating key points. The asperities' densities were assumed to be equal in both plane directions (x,y) and their size were assumed to follow a normal Gaussian distribution with a mean size null and a standard deviation taken as one third of the maximum size.

## 2. Model definition and results

The model consists of an electroplated gold layer defined as a flexible material (Figure 1) with a Young's modulus and a Poisson's ratio taken respectively to 80GPa and 0.42. In our model yield stress was not introduced and the target surface (indenter) is assumed to be a flat, smooth and rigid surface.

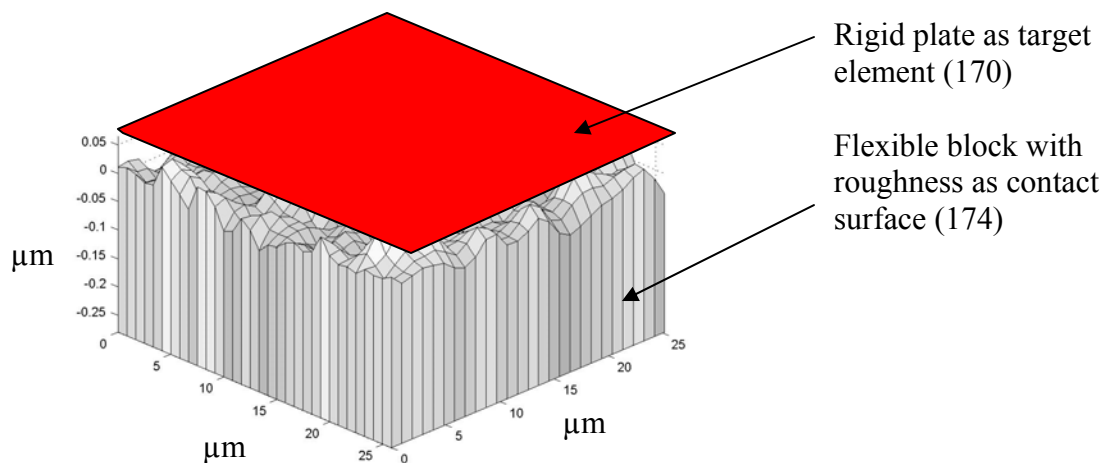


Figure 1: Model definition

To perform the finite element analysis, we choose the combined method based on penalty and lagrangian methods called the *augmented Lagrange method* (see Figure 2). That is a penalty method with penetration control :

- The Newton-Raphson iterations start off similar to the pure penalty method.
- Similar to the pure Lagrange multiplier method, the real constant TOLN determines the maximum allowable penetration.
- If the penetration at a given equilibrium iteration exceeds this maximum allowable penetration, the contact stiffness per contact element is augmented with Lagrange multipliers for contact force (pressure). For the contact element's stiffness, the force (pressure) is:

$$\lambda_{i+1} = \lambda_i + k_{cont} x_{pene}$$

if the penetration is greater than the maximum allowed value.

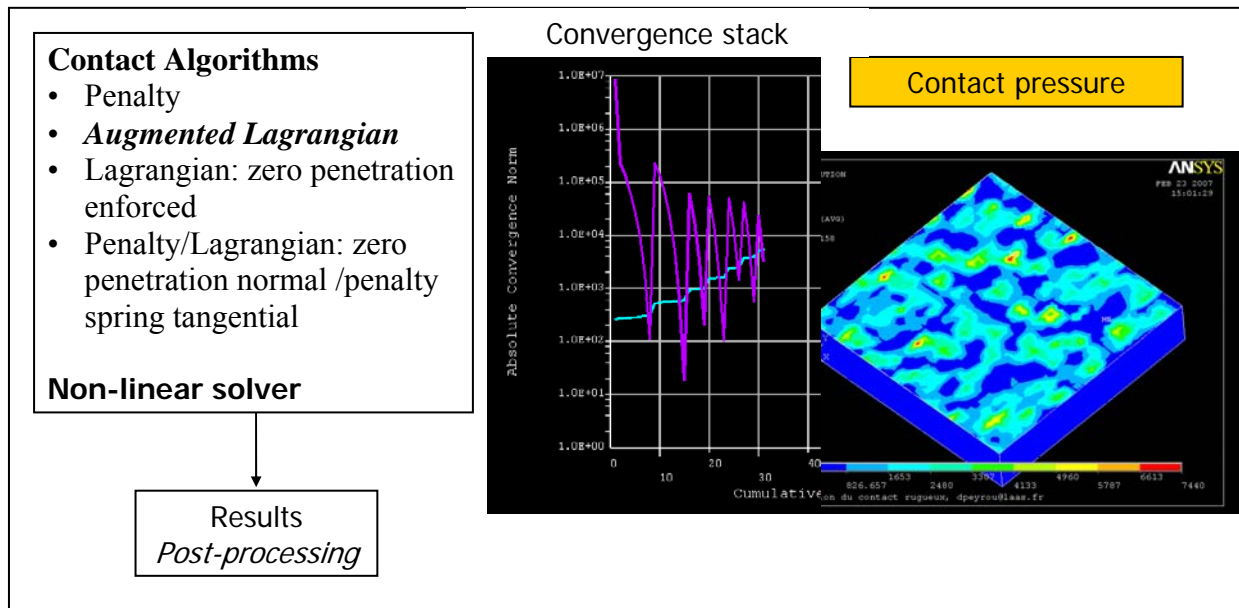


Figure 2: Contact algorithms and post processing in ANSYS

### 3. Results

From the pressure distribution and size of the contact spot we can use an analytical expression to extract the electrical contact resistance. In fact, for both ohmic constriction [1] and boundary scattering, the contact resistance  $R_c$  for a spot of radius  $a$  is [2-3] :

$$R_c = \gamma \left( \frac{\lambda}{a} \right) R_M + R_S = \frac{1 + 0.83 \left( \frac{\lambda}{a} \right)}{1 + 1.33 \left( \frac{\lambda}{a} \right)} \frac{\rho}{2a} + \frac{4\rho\lambda}{3\pi a^2}$$

Where  $\lambda$  is the electron mean free path, and  $\rho$  is the electrical resistivity.  $R_M$  is the Maxwell spreading resistance (the resistance due to lattice scattering, diffusive transport), and  $R_S$  is the Sharvin resistance (the additional resistance due to boundary scattering in small constrictions, ballistic transport).

Thus, we obtained the contact resistance as a decreasing function of the applied force (Figure 3).

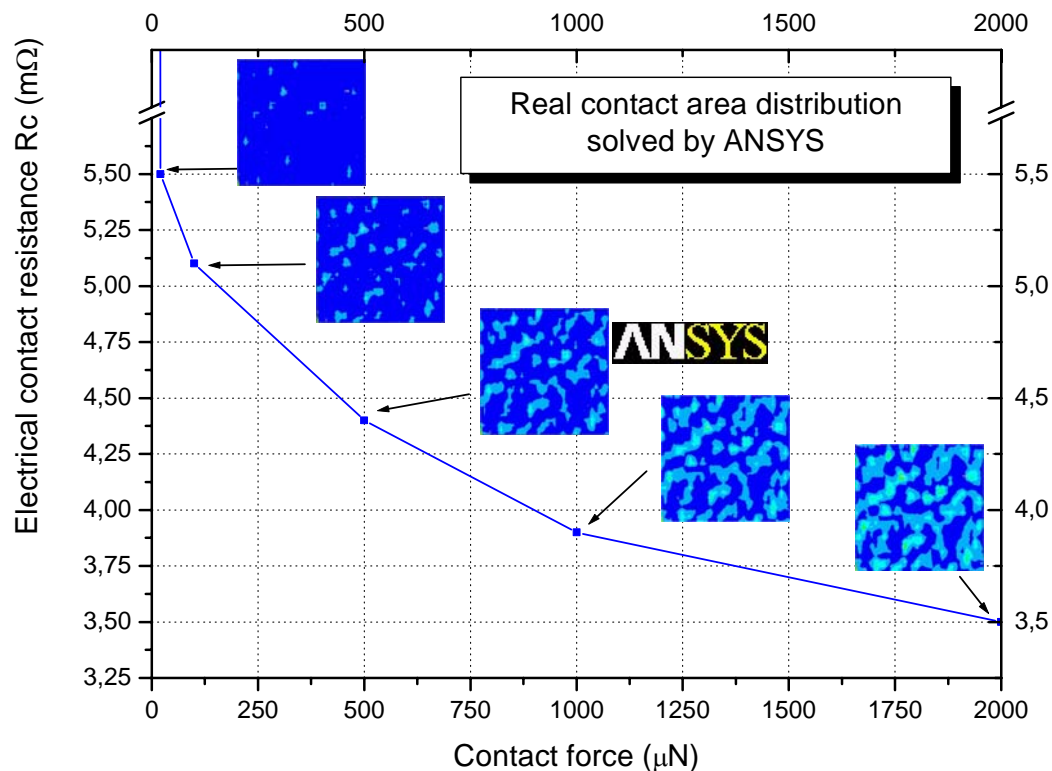


Figure 3: Electrical contact resistance versus contact force

This application shows a powerful method to analyse surface topography effect such as roughness. Due to its great interest, this application would be intensively studied in order to give a guideline for the material choice by studying the impact of different materials' properties and roughness distribution on the resistance. The rough surface generation procedure we have developed, allow us a deterministic calculation of the resistance from the real roughness obtained by reverse engineering method and also a statistical or fractal [4] representation of the roughness.

#### 4. References

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