Rough Surface Modeling of PDMS Polymer Through Fractal Dimensions

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INTRODUCTION

Using fractal geometry to model rough surfaces results in a versatile way to represent a self-similar structure that contains a spatial cutoff frequency, based on a fractional Brownian motion (fBm) as explained by H. Peitgen *et al*., in [1]. This representation is useful to preform irregular creep compliance or contact resistance tests.

Fractals in modeling helps to evaluate the effects of contact resistance in the conductive paths of force sensing resistors (FSRs) [2][3]. This phenomenon is not negligible in some cases and generates drifted measures that could be predicted with an appropriate model, including this self-similar behavior.

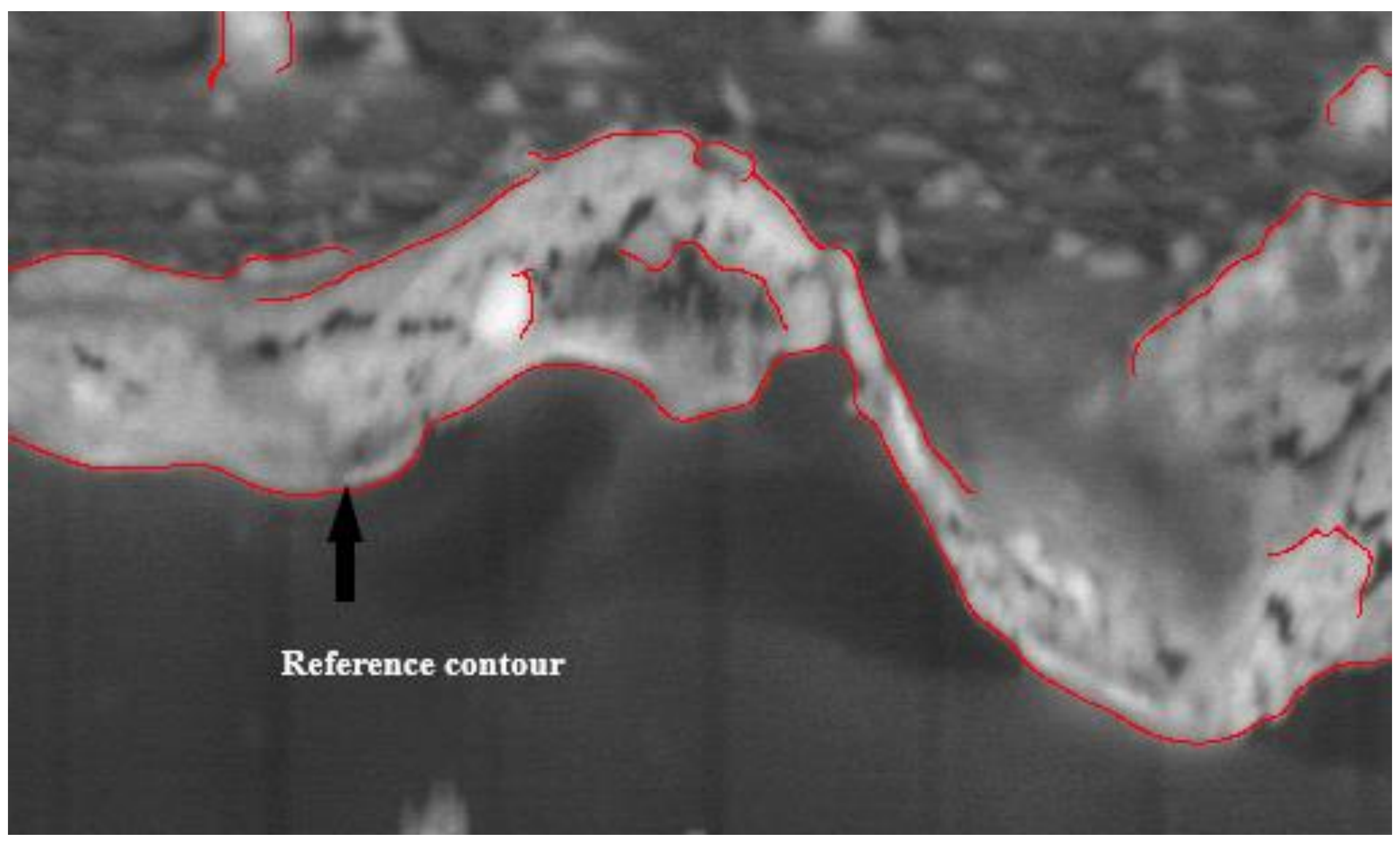

Figure 1. Atomic force microscope image from a doped PDMS sample.

COMPUTATIONAL METHODS

A parametric curve (2D or 3D) is defined as a surface proportional to a Weierstrass-Mandelbrot function, which has a spatial cutoff frequencies (M,L) and depends on random Gaussian distributions A(m,l) and θ(m,l), to sweep the amplitude and phase. This geometry has an exponential decay given by the fractal dimension (D), as follows:

$$S_{2D}(x) = \sum_{m=0}^{M} a(m)^{-D/2} Cos[2\pi(mx)+\theta(m)] \rightarrow 2D\ Contour$$

$$S_{3D}(x,y) = \sum_{l=0}^{L}\sum_{m=0}^{M} a(m,l)^{-D/2} Cos[2\pi(mx+ly)+\theta(m,l)] \rightarrow 3D\ Surface$$

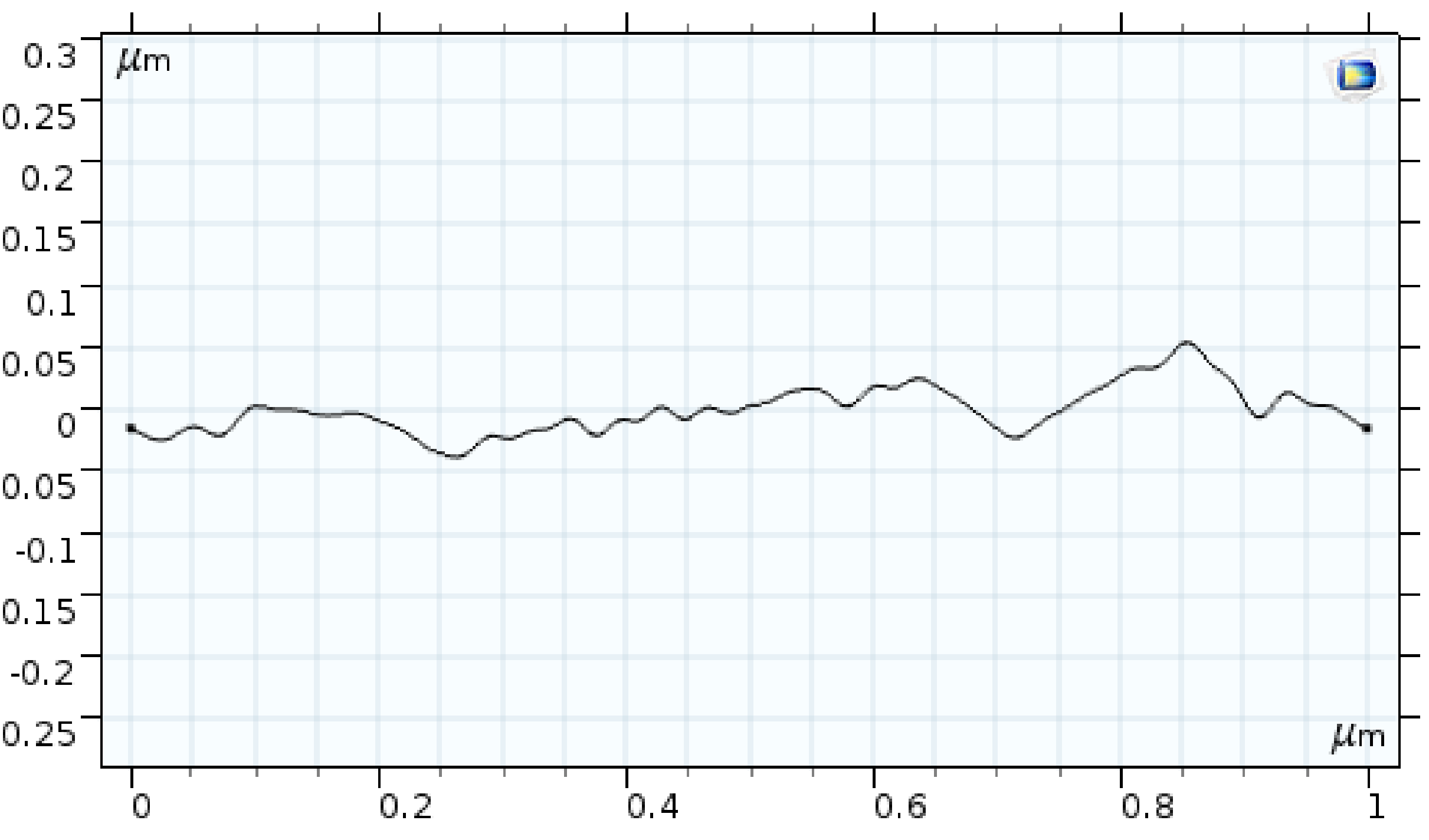

Figure 2. Parametric 2D contour with N=30, H=0.6, D=1.4

RESULTS

The 2D and 3D geometries obtained are intended to be applied in creep compliance and contact resistance tests. Considering the rheological behavior of the polymer, the following geometries were obtained:

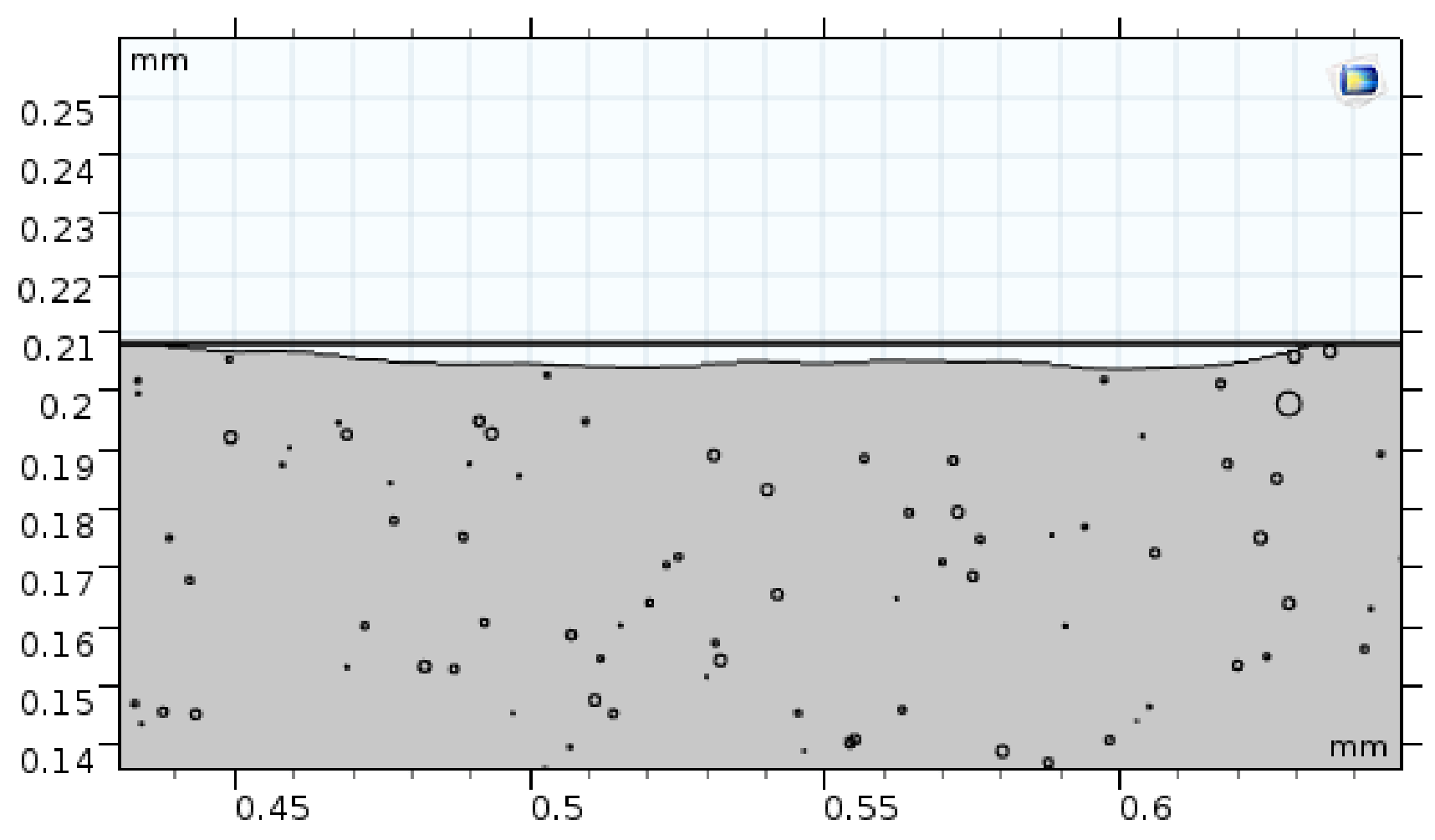

Figure 3. 2D geometry contour with M=50, D=1.6 and H=0.4.

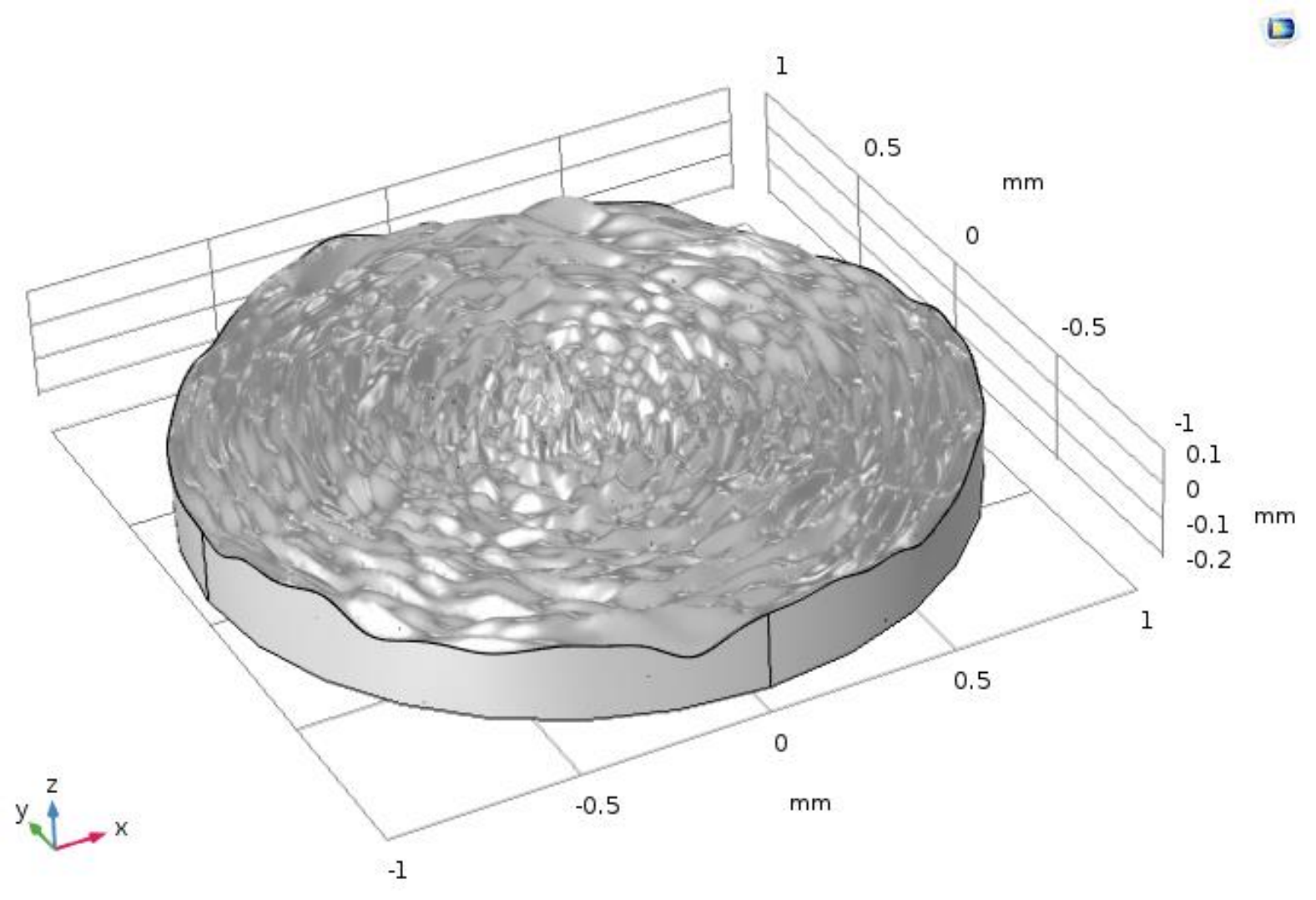

Figure 4. 3D geometry surface with M=L=50, D=2.95 and H=0.05.

With a pressure of 200[kPa] applied to a polymer sample at the edge, the expected irregular strain occurred for a stationary study, using the solid mechanics module.

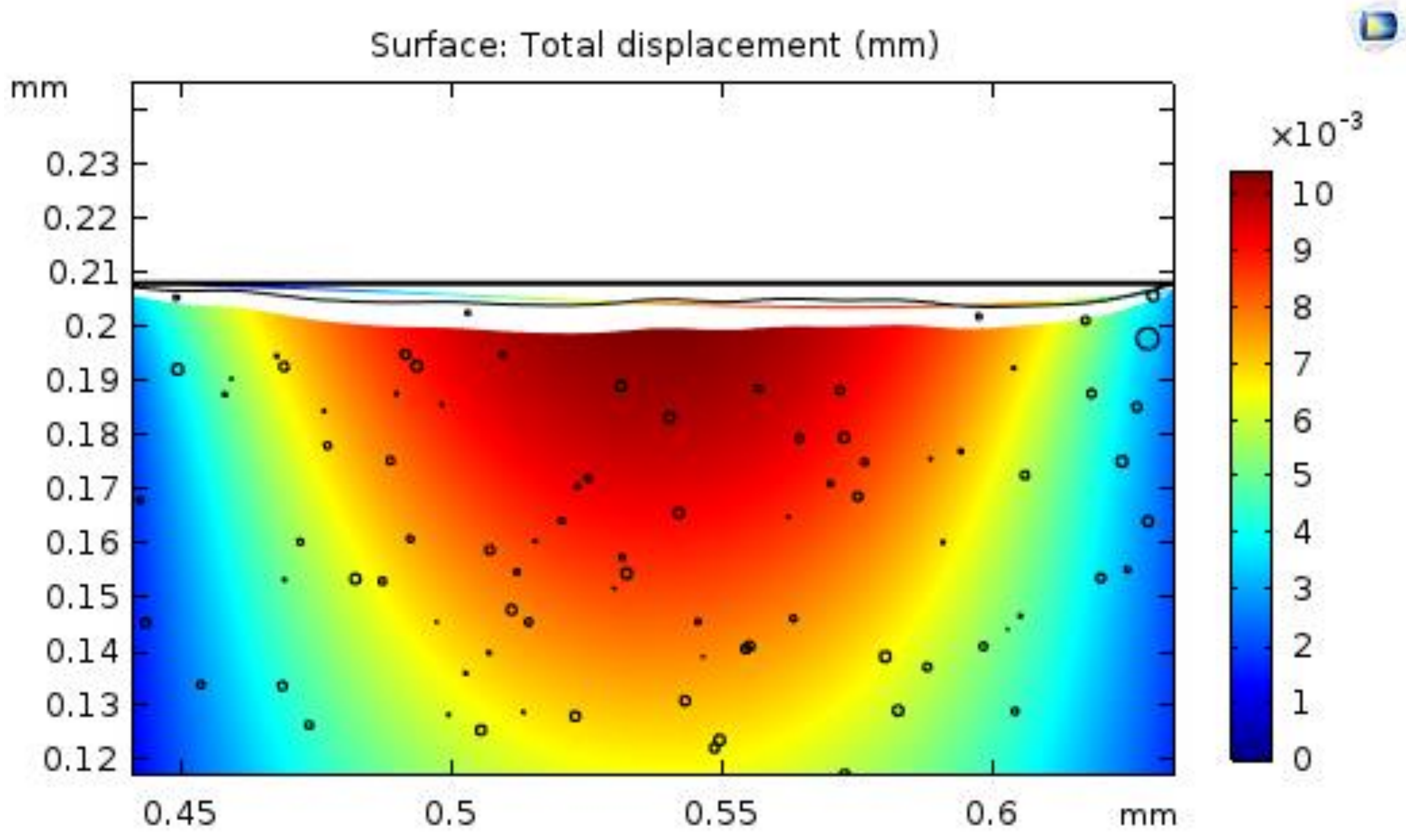

Figure 5. Creep compliance test with irregular strain.

CONCLUSIONS

Using this method to generate rough surfaces with a fractal dimension defined by a Hurst exponent, results in contours or surfaces with the desired roughness level in which creep compliance and contact resistance can be studied. This process generates valleys in the geometry, which are necessary to study the changes produced in the conductive paths of a PDMS sample doped with conductive nanoparticles and subjected to a certain strain.

REFERENCES

1. H. Peitgen, D. Saupe and M. Barnsley, The science of fractal images. New York: Springer-Verlag, 1988.
2. L. Paredes-Madrid, A. Matute, J. Bareño, C. Parra Vargas and E. Gutierrez Velásquez, "Underlying Physics of Conductive Polymer Composites and Force Sensing Resistors (FSRs). A Study on Creep Response and Dynamic Loading", Materials, vol. 10, no. 11, p. 1334, 2017.
3. L. Paredes-Madrid, C. Palacio, A. Matute and C. Parra Vargas, "Underlying Physics of Conductive Polymer Composites and Force Sensing Resistors (FSRs) under Static Loading Conditions", Sensors, vol. 17, no. 9, p. 2108, 2017.