



HAL
open science

3D finite element model of elastoplastic contact on the double sinus rough surface

H Hagege, Salima Bouvier, P.-E. Mazeran, Maxence Bigerelle

► **To cite this version:**

H Hagege, Salima Bouvier, P.-E. Mazeran, Maxence Bigerelle. 3D finite element model of elastoplastic contact on the double sinus rough surface. *Journal of Physics: Conference Series*, 2011, 311, pp.012011. 10.1088/1742-6596/311/1/012011 . hal-04546078

HAL Id: hal-04546078

<https://hal.science/hal-04546078>

Submitted on 15 Apr 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

OPEN ACCESS

3D finite element model of elastoplastic contact on the double sinus rough surface

To cite this article: H HAGEGE *et al* 2011 *J. Phys.: Conf. Ser.* **311** 012011

View the [article online](#) for updates and enhancements.

You may also like

- [Effects of surface roughness and counter body variables on the dry sliding wear behavior of AISI 4140 steel based on the elastoplastic flattening model](#)
Yilmaz Küçük, Azmi Erdoan, Bilal Kuruncu et al.
- [Semi-supervised deep networks for plasma state identification](#)
Matj Zorek, Vít Škvára, Václav Šmídl et al.
- [Early Planet Formation in Embedded Disks \(eDisk\). XIV. Flared Dust Distribution and Viscous Accretion Heating of the Disk around R CrA IRS 7B-a](#)
Shigehisa Takakuwa, Kazuya Saigo, Miyu Kido et al.

PRIME
PACIFIC RIM MEETING
ON ELECTROCHEMICAL
AND SOLID STATE SCIENCE

HONOLULU, HI
Oct 6-11, 2024

Abstract submission
deadline extended:
April 19, 2024
Learn more and submit!

Joint Meeting of
The Electrochemical Society
•
The Electrochemical Society of Japan
•
Korea Electrochemical Society

3D finite element model of elastoplastic contact on the double sinus rough surface

H HAGEGE¹, S BOUVIER¹, P-E MAZERAN¹ and M BIGERELLE¹

¹ Laboratoire Roberval, UMR 6253, UTC/CNRS, UTC Centre de Recherches de Royallieu BP 20529, 60205 Compiègne, France.
E-mail: benjamin.hagege@utc.fr

Abstract. One of the objectives in the field of tribology is to solve the mechanical stress-displacement problem involved by rough contacts. In our approach, the surface chosen is a 256-256 μm^2 3D sinusoidal shape (amplitude 4.5 μm , wavelength 50 μm) with an elastoplastic constitutive behaviour. The constitutive law combines isotropic and kinematic hardening and is experimentally identified from 316L steel sheets. The FEM deformable surface is crushed then uncrushed by a rigid flat surface: stresses, contact pressure and plastic cumulated strain are computed. We investigate the results sensitivity with respect to the level of in-plane refinement. At last, we conclude on some guidelines for 3D finite elements modelling of rough surfaces.

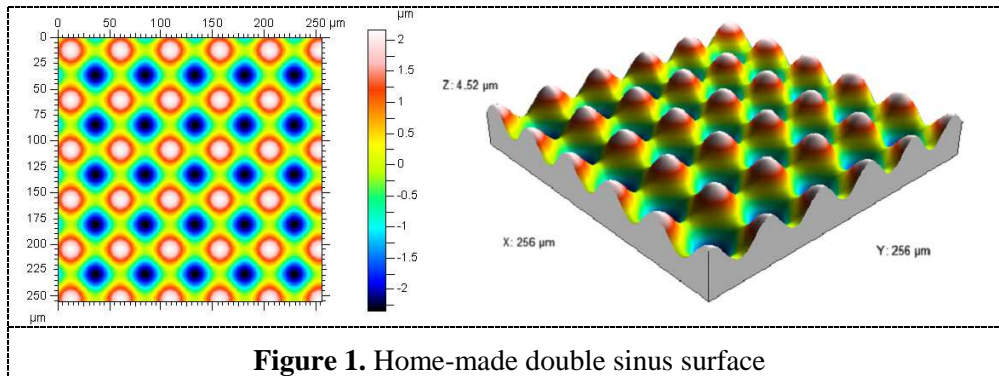
1. Introduction

Tribology analysis of surfaces is traditionally associated with stochastic and semi-analytical models. But the assumptions made are sometimes too restrictive because of 3D geometry of surfaces and non-linear elastoplastic behavior of materials. Nevertheless, in order to model more precisely the response of a rough surface, many authors modeled the contact with Finite Elements Method (FEM). However, because of the large size of such numerical models, computations are still often restrained to 2D plane-strains slices, from which the surface is supposed to be ‘extruded’, despite 3D approaches have been already tried by [1]. 3D models allow to estimate with more accuracy the stress field and to take into account the “geometric coupling” between asperities, but computation times dramatically increase with mesh density. However, by means of new shared memory computing blades and with adequate softwares (i.e. Ansys Academic ResearchTM), it becomes possible to analyse 3D elastoplastic contact of realistic discretized surfaces. Our objective is to develop a finite elements mechanical computation methodology of rough surfaces.

2. Materials and the finite element model

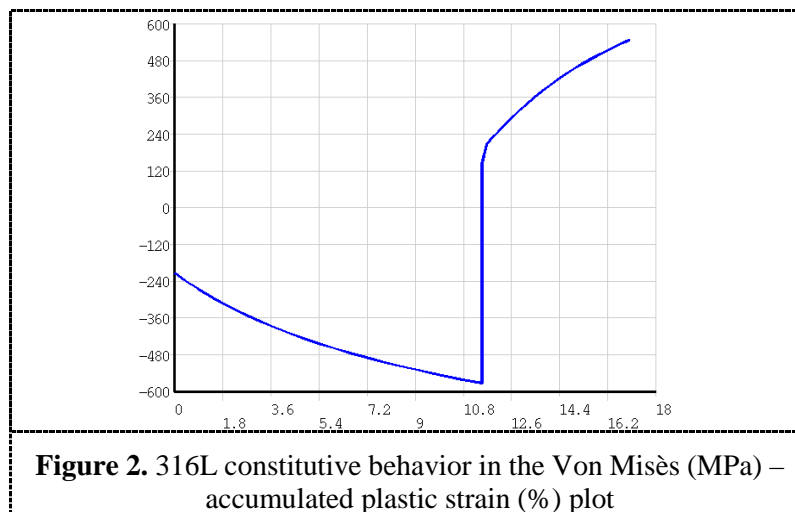
The studied surface is showed on Fig. 1: it is simple because of its geometry regularity and it is a reference case because of the sinus asperities shape [2]. Because of the “low” roughness of this surface, the finite elements mesh is obtained by perturbation of a pre-existing mapped mesh. Perturbation consists in the displacement of the surface nodes by spatial detection and comparison to an input file coming from a profilometer device. The low R_f parameter (compared to the wavelength of an asperity) allows the generation without “folded” elements.

¹ To whom any correspondence should be addressed.



2.1. Constitutive behavior

The material is a 316L steel with an initial yield stress of 212.54MPa described by the Lemaître-Chaboche hardening: isotropic Voce hardening (saturation $R_{inf}=1000\text{MPa}$ and exponent $b=1.6$) plus one term Armstrong-Frederick kinematic hardening (parameters $C1=4836.4\text{MPa}$ and $G1=23.5$). Young modulus is 200GPa and $\nu=0.3$. The 1D material law in compression then tension is showed on Fig. 2.



2.2. Finite elements meshes and boundary conditions

The input file is done with $1\mu\text{m}$ space increments in X and Y directions. As the surface is a $256\mu\text{m}$ square, maximum density corresponds to a mesh size of 256×256 elements on surface, like mesh 3, whereas meshes 2 and 1 are successively twice less dense (see Fig. 3). Mesh 101 corresponds to mesh 1, but with parabolised H20 elements coming from the H8 mesh of 1. All these meshes have a thickness of $256/8.5\mu\text{m}=30.12\mu\text{m}$.

The modeled substrate comes from a sample (dimensions: $1\text{cm}^2 \times 1\text{cm}$) that is free on its four sides and that lies on a plane on its underside. Because of symmetries, we also take free edges for the substrate, however, the substrate bottom is simply supported in the Z direction, leading in overestimated stiffness, and so are the stresses and plastic strains. The rigid surface crusher is displacement driven

along Z with all other degrees of freedom blocked. Surface goes down to $R_t/4=1.13\mu\text{m}$ and goes back up to $0.904*R_t/4$ to finely analyse the spring-back. Regarding the interface behavior, it is desirable to employ an exact contact algorithm since the problem is dominated by contact mechanics. This is why the Pure Lagrangian algorithm is chosen. There is no friction.

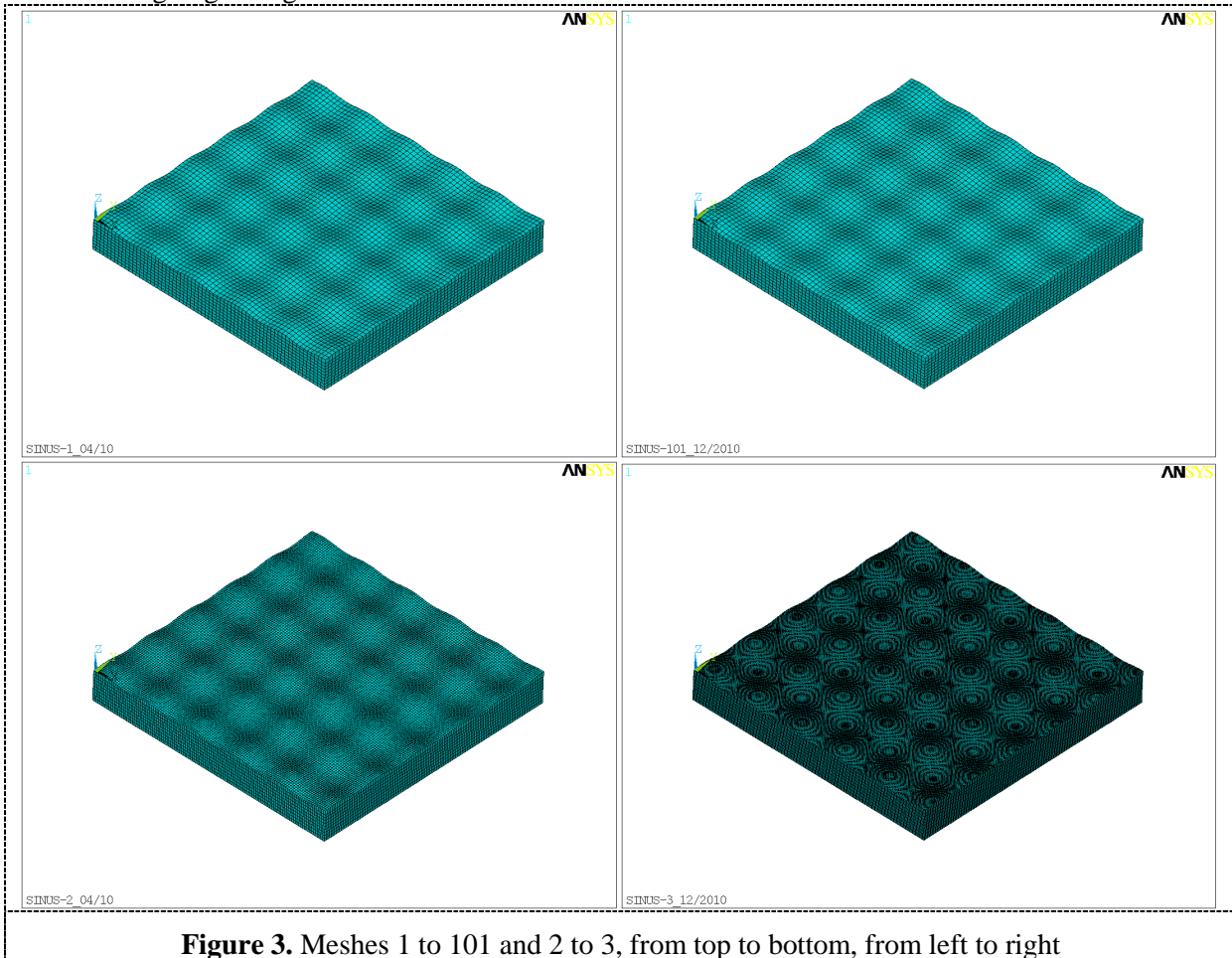


Figure 3. Meshes 1 to 101 and 2 to 3, from top to bottom, from left to right

2.3. Model parameters and numerical performance

We summarize the different models on Tab. 1 and we emphasize the large numerical resources needed to run them. The supercomputer used was a BULL 6030 Supernode with 24 X7542 Xeon cores, 256Gb RAM and 3.2To stripped 10kRPM HD. All models have 10 elements in the Z thickness direction.

Table 1. Parameters and numerical performances

JOB	MESH		NUMERICAL PERFORMANCES			
	Nb elem. X	Nb elem. Y	Nb dof	Nb Core	Comp. Time (s)	Required RAM to run incore (Mo)
1	64	64	132345	5	2732	945
101	64	64	519919	4	42104	8017
2	128	128	526841	6	15794	4759
3	256	256	2096612	6	100604	23947

3. Convergence analyses

3.1. Convergence of macroscopic out of plane force and contact area

Fig. 4 highlights a quick convergence of the FZ reaction force of the rigid surface and of the total contacted area: model 2 with 128x128 elements on surface is suitable whereas models 1 and 101 with 64x64 elements are too coarse.

Despite it is not needed, model 3 is the best but at a large computing cost (see Tab. 1).

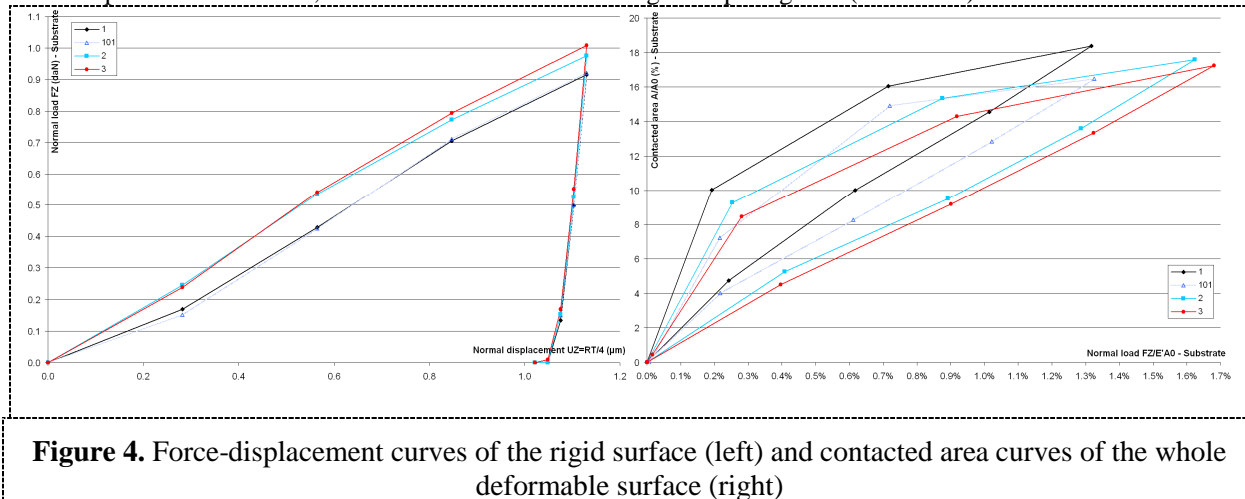


Figure 4. Force-displacement curves of the rigid surface (left) and contacted area curves of the whole deformable surface (right)

3.2. Convergence of the Von Mises stress at the end of the crush step

On one hand, we show on Fig. 5 that only model 3 allows to obtain the fine distribution of in plane surface maximum values that are the crowns around the maximum contact areas (between 400MPa and 450MPa in orange range). On the other hand, the maximum Von Mises stress is found beneath the surface, below the top of asperities as expected by extending the classic elastic Hertz theory of contact to elastoplasticity. All meshes localize well this stress peak and lead to values between 470 and 491MPa.

Model 3 is the best and is needed for good in plane discretization.

4. Conclusion

We have demonstrated the feasibility of 3D finite elements computations in the case of the regular double sinus rough surface. We may conclude on guidelines to start to build a general methodology. Here are the 2 main conclusions:

- quadratic elements are not recommended because they do not improve the discretized contact state, that must be finely described, while they dramatically increase computing time,
- in order to finely discretize the in plane Von Mises stress field, fine meshes with in plane 256x256 element densities are needed (element size = 1µm that is 50 elements / wavelength here).

Thereafter, it will be necessary to analyze residual stresses at the end of the “uncrush” step. Moreover, to have a more realistic 3D approach, friction and sample stiffness must be taken into account with the aid of a spring.

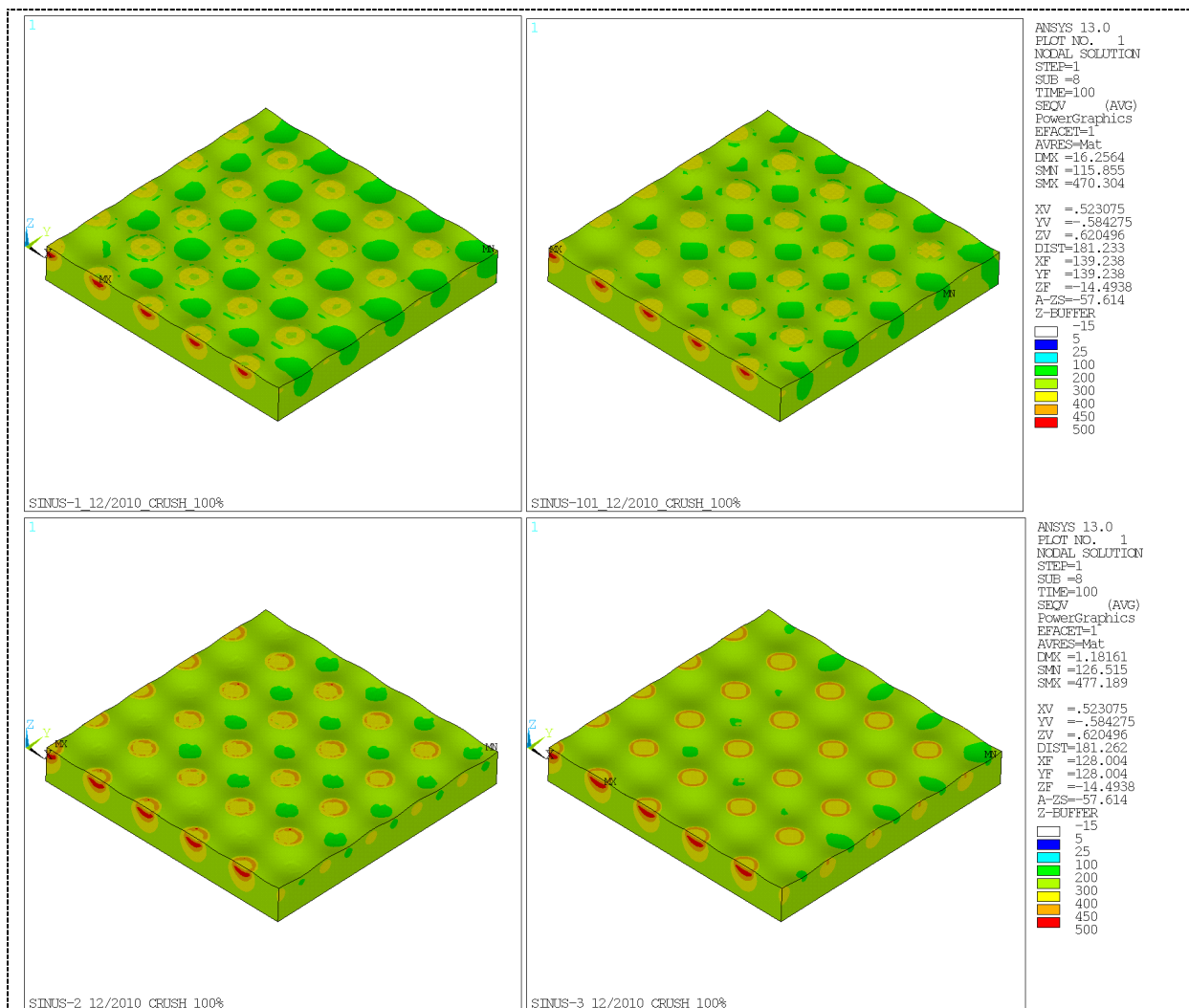


Figure 5. Von Mises stress field for meshes 1 to 101 and 2 to 3, from top to bottom, from left to right

5. References

- [1] Mahrenholtz O, Bontcheva N and Iankov R 2005 *J. Mater. Proc. Tech.* **159** 9
- [2] Söderberg A and Björklund S *Trib. Int.* **41** 926

Acknowledgments

The authors acknowledge the Projet Pluri-Formations PILCAM2 at the Université de Technologie de Compiègne (UTC) for providing HPC resources that have contributed to the research results reported within this paper. URL: <http://pilcam2.wikispaces.com>.