Indentation of Grade 91 Alloy Steel

K. E. Johanns, J. E. Swindeman, and C. C. Oliver, Nanomechanics, Inc.

Introduction

Ferritic-Martensitic low-carbon alloy steels have applications in pressure vessels, piping, and nuclear reactors due to their advanced material properties at higher temperatures. Specifically, grade 91 or P91 alloy (9CrMo) steel (Table 1) has enhanced creep resistance at higher temperatures. First, we implement the **electromagnetic actuation** and **dynamics** of Nanomechanics, Inc. nanoindenters to measure the elastic modulus of grade 91 steel as a function of indentation load and depth (Figure 1).

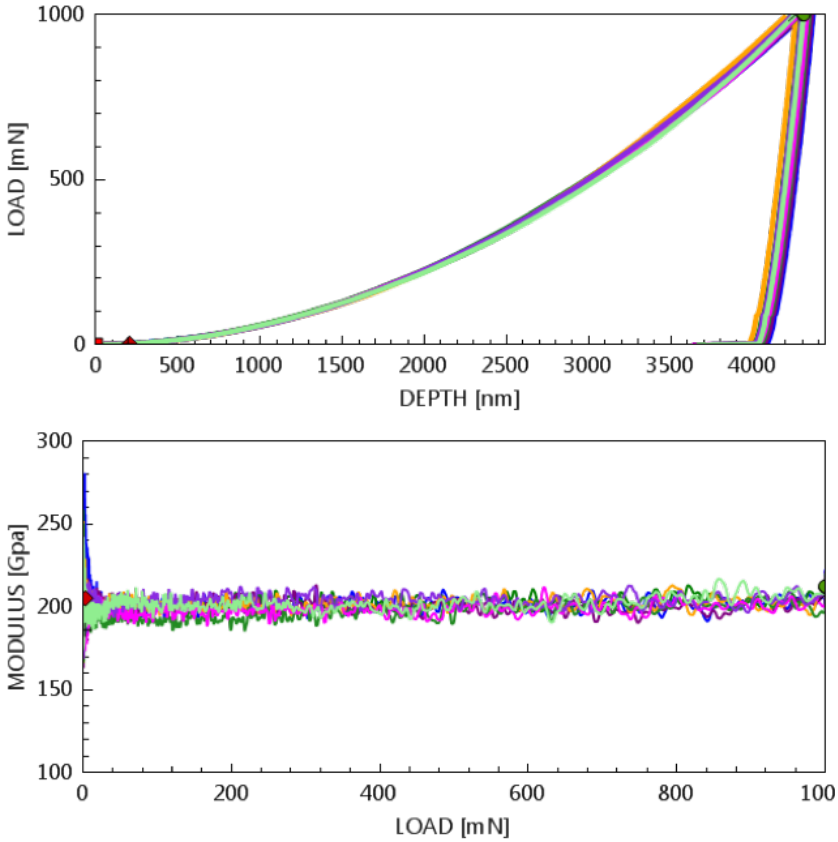

Figure 1 *– Nanoindentation testing results on Grade 91 steel using an iMicro nanoindenter. A load is applied and the resulting indentation depth is measured. Material properties, such as elastic modulus, are measured continuously during the load application. This results in a dataset that can be used to assess the mechanical behavior of surfaces.*

Table 1 – Mechanical Properties and Composition of Grade 91 Alloy Steel

Typical Mechanical Properties	Value
Ult. Tensile Strength	585 - 760 MPa
Yield Strength	415 MPa
Elongation at Break	18 %
Elastic Modulus	200 GPa
Poisson's Ratio	0.29

Element	Weight %
Fe	Balance
Cr	8.00 - 9.50
Mo	0.85 - 1.05
Mn	0.30 - 0.60
Si	0.20 - 0.50
V	0.18 - 0.25
C	0.08 - 0.12
Nb	0.06 - 0.10
N	0.03 - 0.07

NanoBlitz 3D – Rapid Statistical Quantification

In addition, we highlight the power of high-speed indentation and the generation of powerful statistical data with **NanoBlitz 3D**. A total of 3600 individual indentations were conducted over an area of 100µm x 100µm with NanoBlitz 3D in an **iMicro®** system at an applied load of 2mN. The total test time for all 3600 indentations was 2800s, resulting in a fast yet large dataset that highlights the statistical power and efficiency of NanoBlitz 3D.

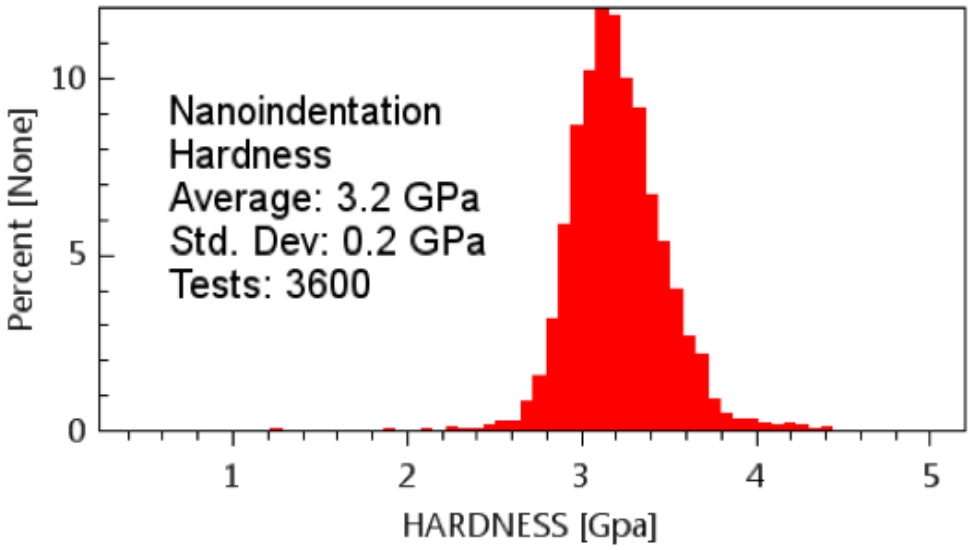

Figure 2 *– Probability distribution function of nanoindentation hardness from 3600 individual indents on Grade 91 steel.*

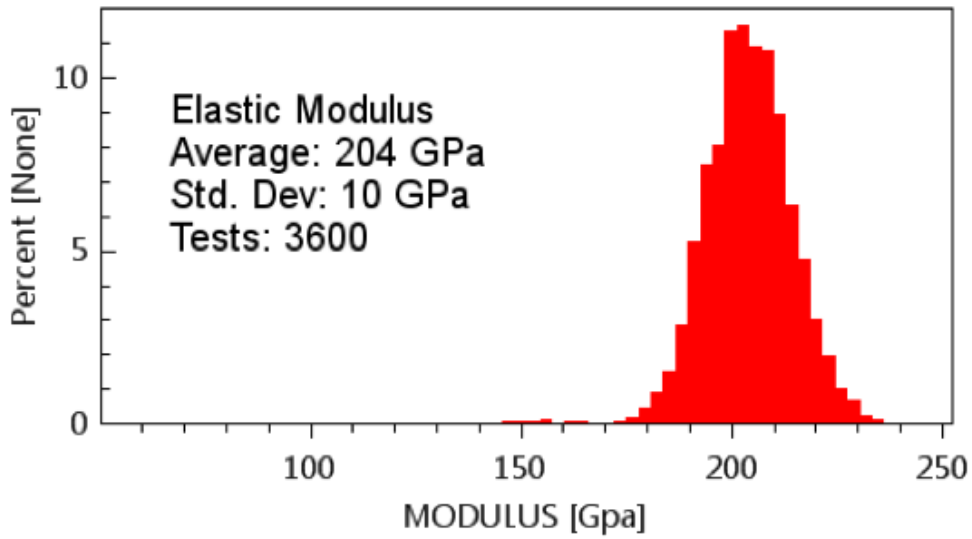

Figure 3 *– Probability distribution function of elastic modulus from 3600 individual indents on Grade 91 steel.*