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Experience in Tensile Properties Determination by Small Punch Test

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Small Sample Test Techniques
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INTRODUCTION

EESTI POWER PLANT

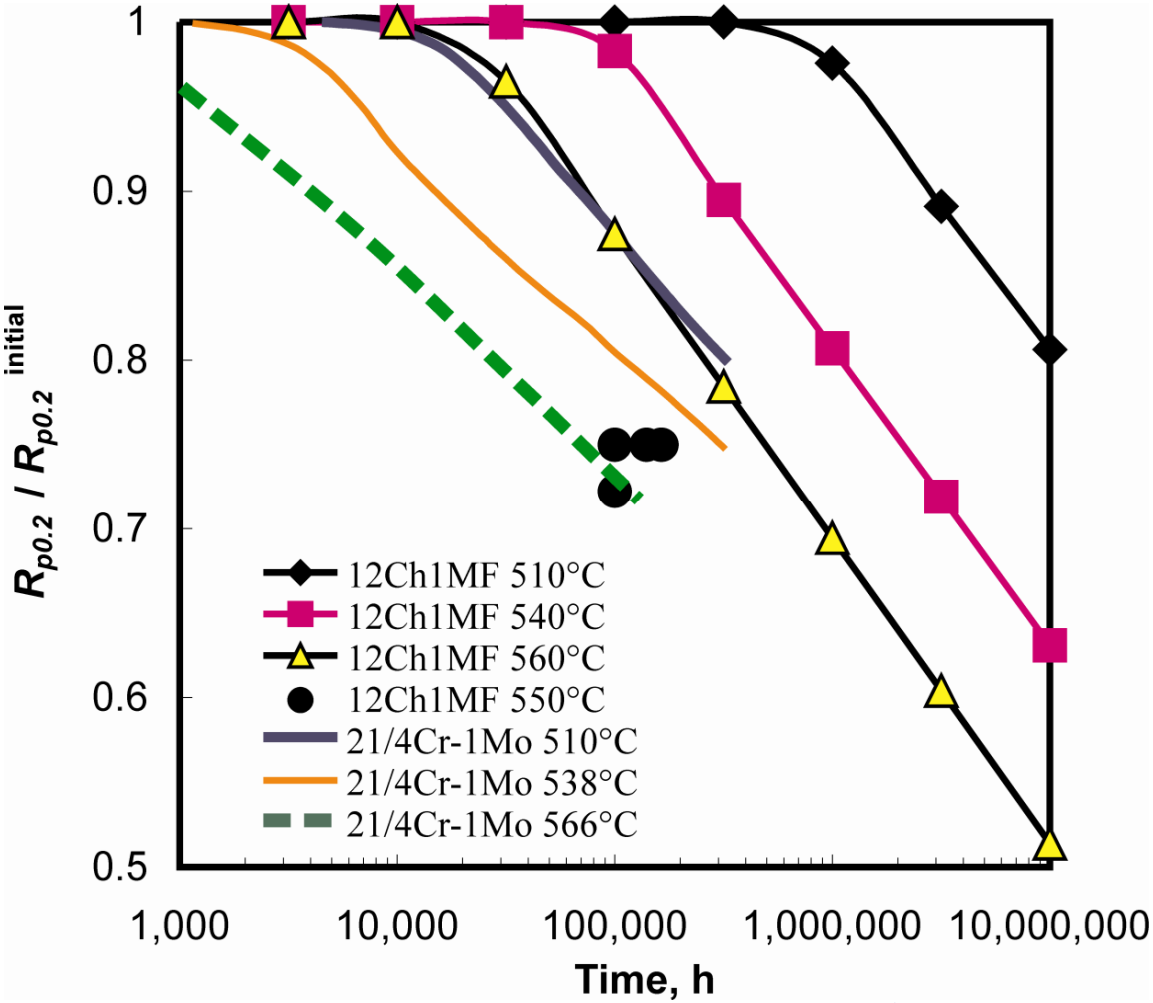
BALTI POWER PLANT

SERVICE TIME EFFECT

The basic components of power plants are operated under creep conditions.

Long-term exposure in such conditions causes inevitable degradation of the structure and properties of the materials used in power plants.

YIELD STRENGTH DEGRADATION



Effect of service time and temperature on the yield strength of steels 12Ch1MF and 2¼Cr-1Mo determined at room temperature.

SERVICE TIME EFFECT

The decrease of short-term mechanical properties for some steels is specified in standards.

The ratio of yield strength to tensile strength ($R_{p0.2}/R_m$) measured at room temperature should also satisfy certain requirements.

СО 153-34.17.421 (RD 10-577-03) Instruction of metal control and life extension of basic components of boilers, turbines and piping at power plants, 2003 (in Russian).

INSPECTION

In order to increase the operating integrity and reliability of the power equipment it is highly significant to be able to estimate the current state of metal damage or life consumption as accurate as possible for in-service components.

PROPERTIES CONTROL

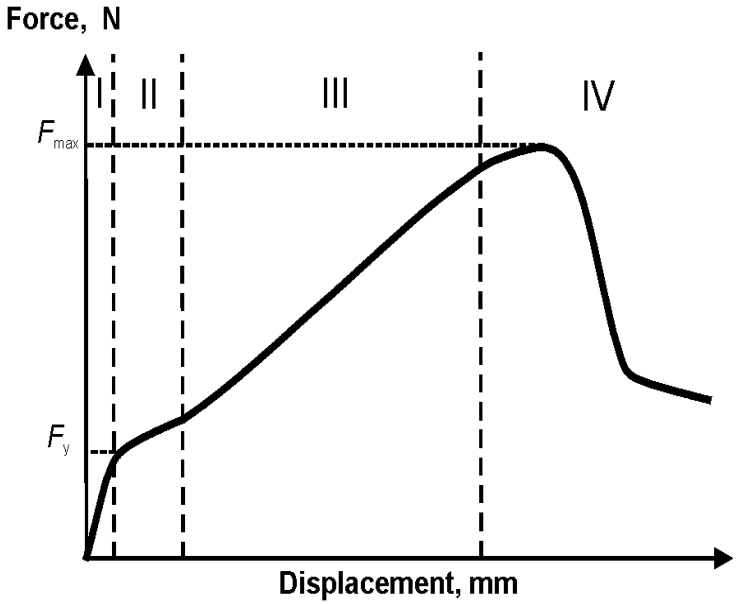
Traditional destructive methods of mechanical properties evaluation require removing metal from the component in great quantities and could not be applied without replacement of the component.

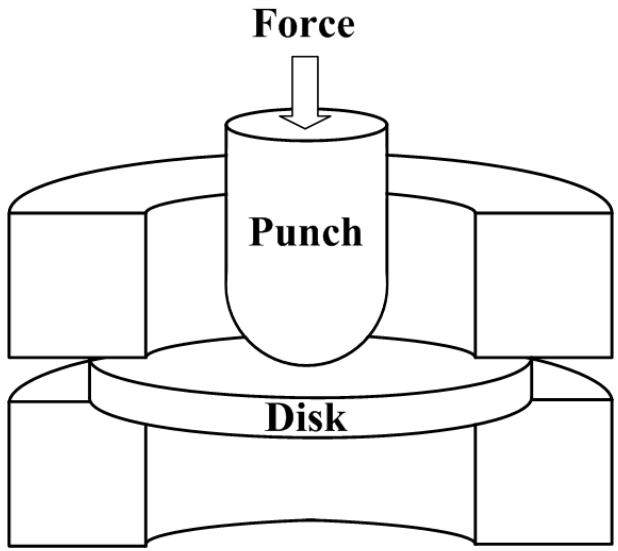
In order to allow continued safe operation of the component, the metal sample should be small enough!

OUTLINE

1. INTRODUCTION
2. EXPERIMENTAL
3. RESULTS
4. CONCLUSIONS

SMALL PUNCH TEST (SPT)





OBJECTIVE

The objective of the present work was to analyse the ability to determine the tensile properties of the power plant components material by means of SP testing technique **at room temperature**

EXPERIMENTAL

Metal sampling from power plant components

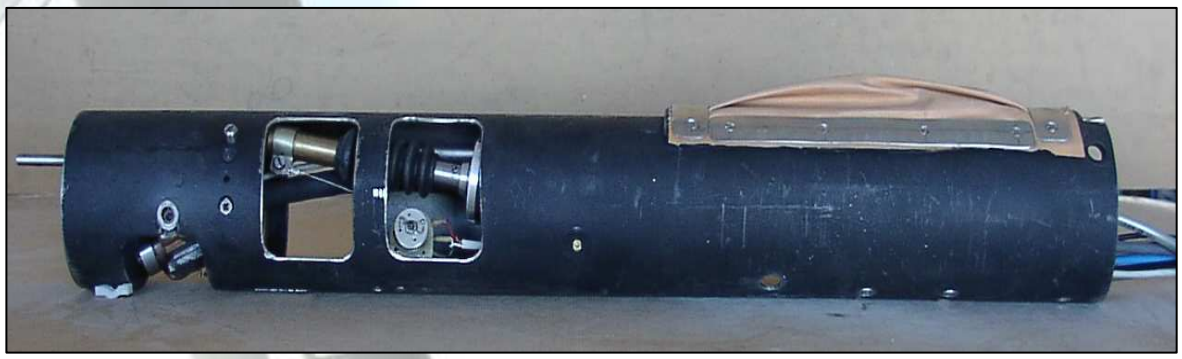
Specimens fabrication

Small Punch Testing

Conventional tensile testing

SAMPLING DEVICES

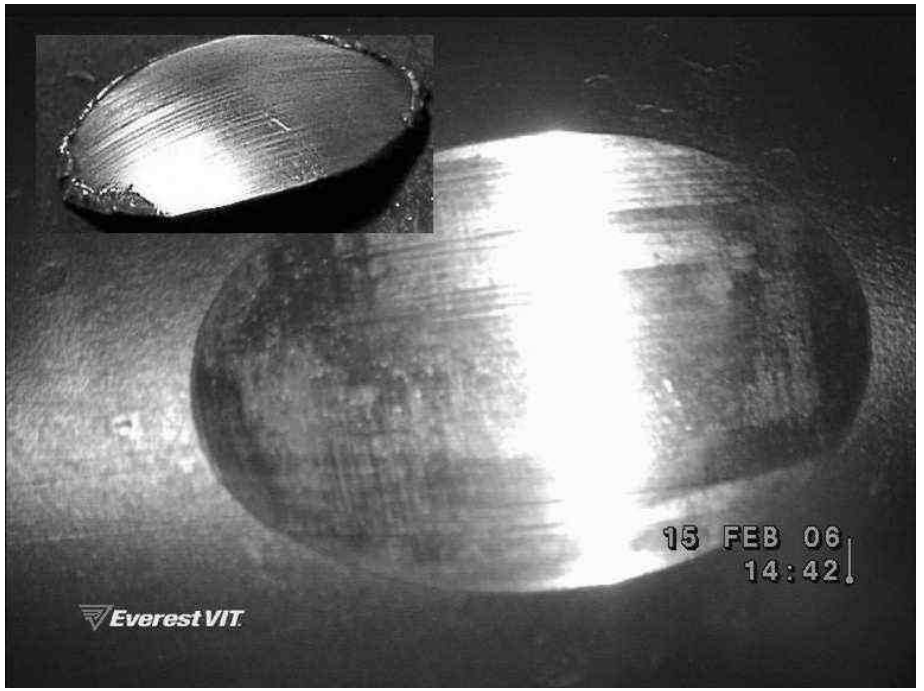
Metal Sampling Machine (MSM-1)



Metal Sampling Machine (MSM-2)

SAMPLING

Cutting element



Extracted sample and dimple

EXPERIMENTAL

Metal sampling from power plant components

Specimens fabrication

Small Punch Testing

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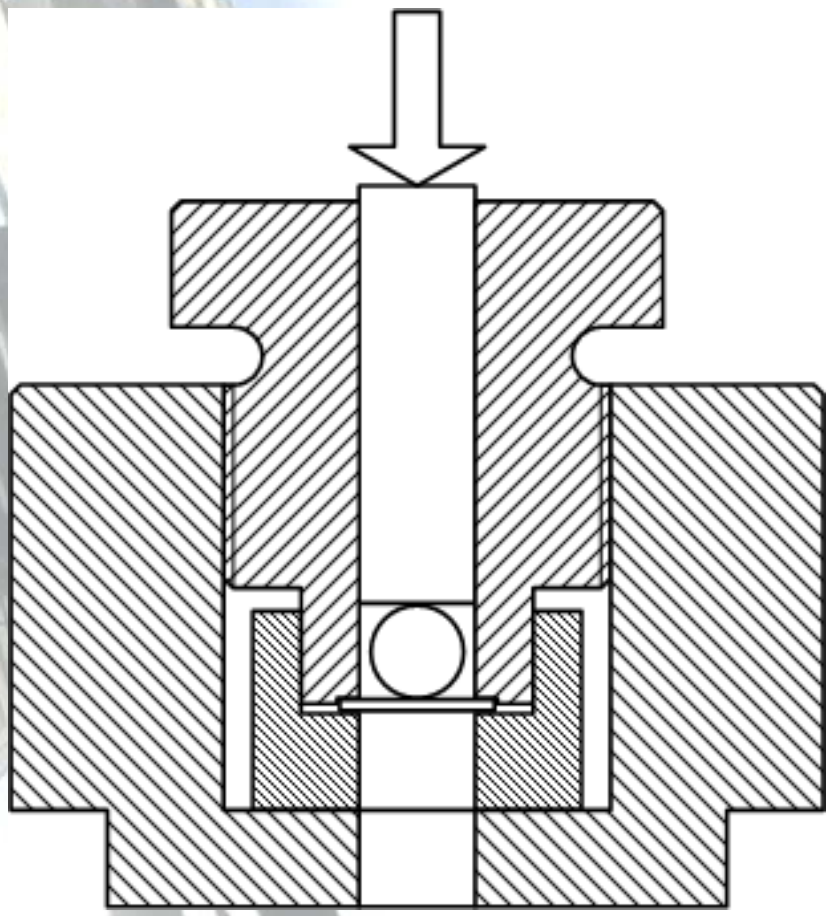
EXPERIMENTAL

Chemical composition of investigated power plant steels

Steel Grade	Content, wt.%										
	C	Si	Mn	Cr	Ni	Mo	V	W	Cu	S	P
20	0.17–0.24	0.17–0.37	0.35–0.65	max 0.25	max 0.3				max 0.3	max 0.04	max 0.035
12Ch1MF	0.08–0.15	0.17–0.37	0.4–0.7	0.9–1.2	max 0.3	0.25–0.35	0.15–0.3	max 0.2	max 0.2	max 0.025	max 0.03
16GNM	0.12–0.18	0.17–0.37	0.8–1.1	max 0.3	1.0–1.3	0.4–0.55			0.15–0.25	max 0.04	max 0.035
12Ch11V2MF	0.10–0.17	max 0.5	0.5–0.8	11–13	max 0.6	0.6–0.9	0.15–0.3	1.7–2.2	max 0.3	max 0.025	max 0.03

EXPERIMENTAL (SPT)



Diameter of disc	8 mm
Thickness of disc	0.5 mm
Diameter of punch indenter	4.8 mm
Punch velocity	~0.042 mm/s (2.5 mm/min)

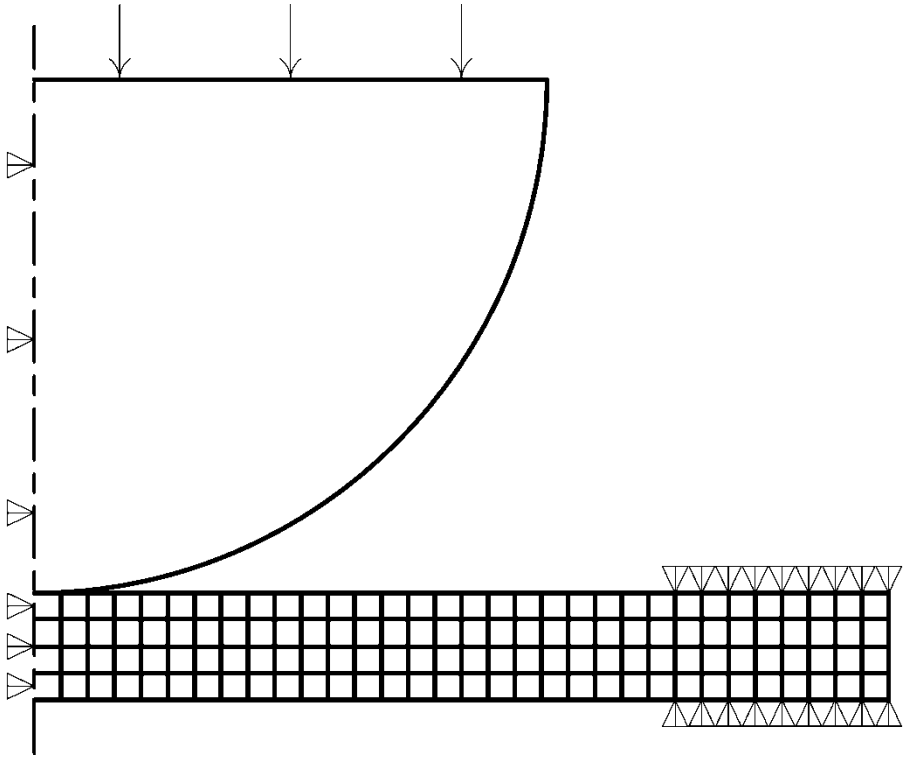
Small punch testing fixture

EXPERIMENTAL (SPT)

Small punch testing unit

EXPERIMENTAL (FEM)

2D finite element model



Friction coefficient	0.3
Poisson's ratio	0.3
Young's modulus, N/m^2	$2 \cdot 10^{11}$

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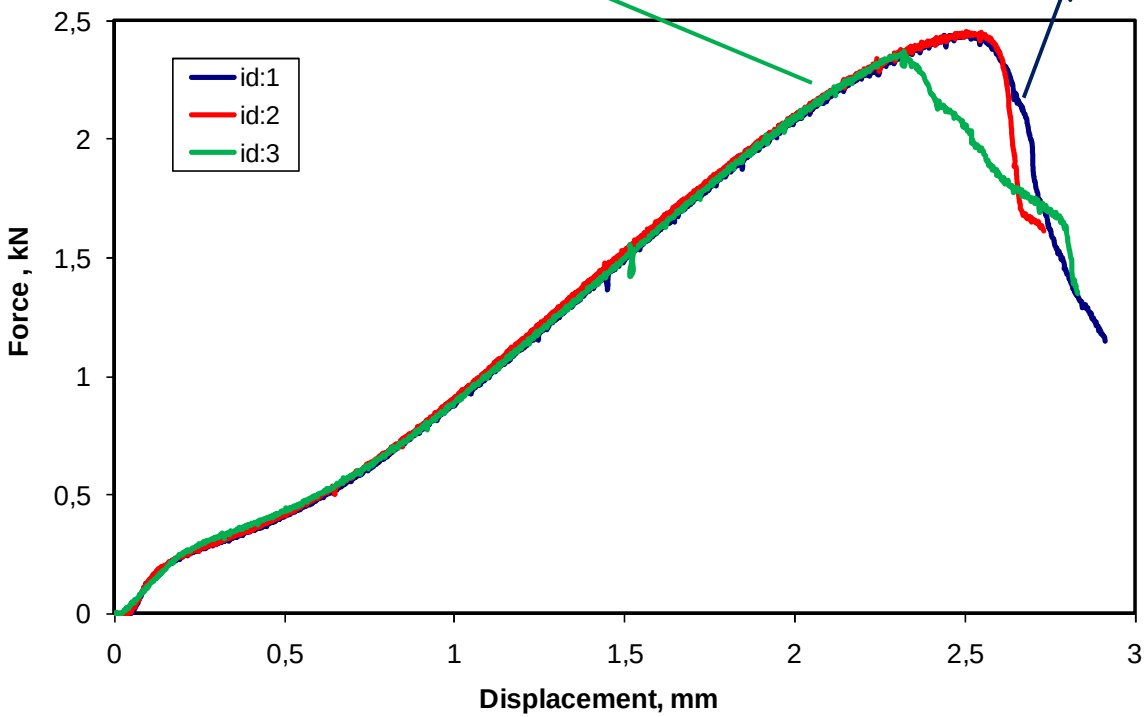
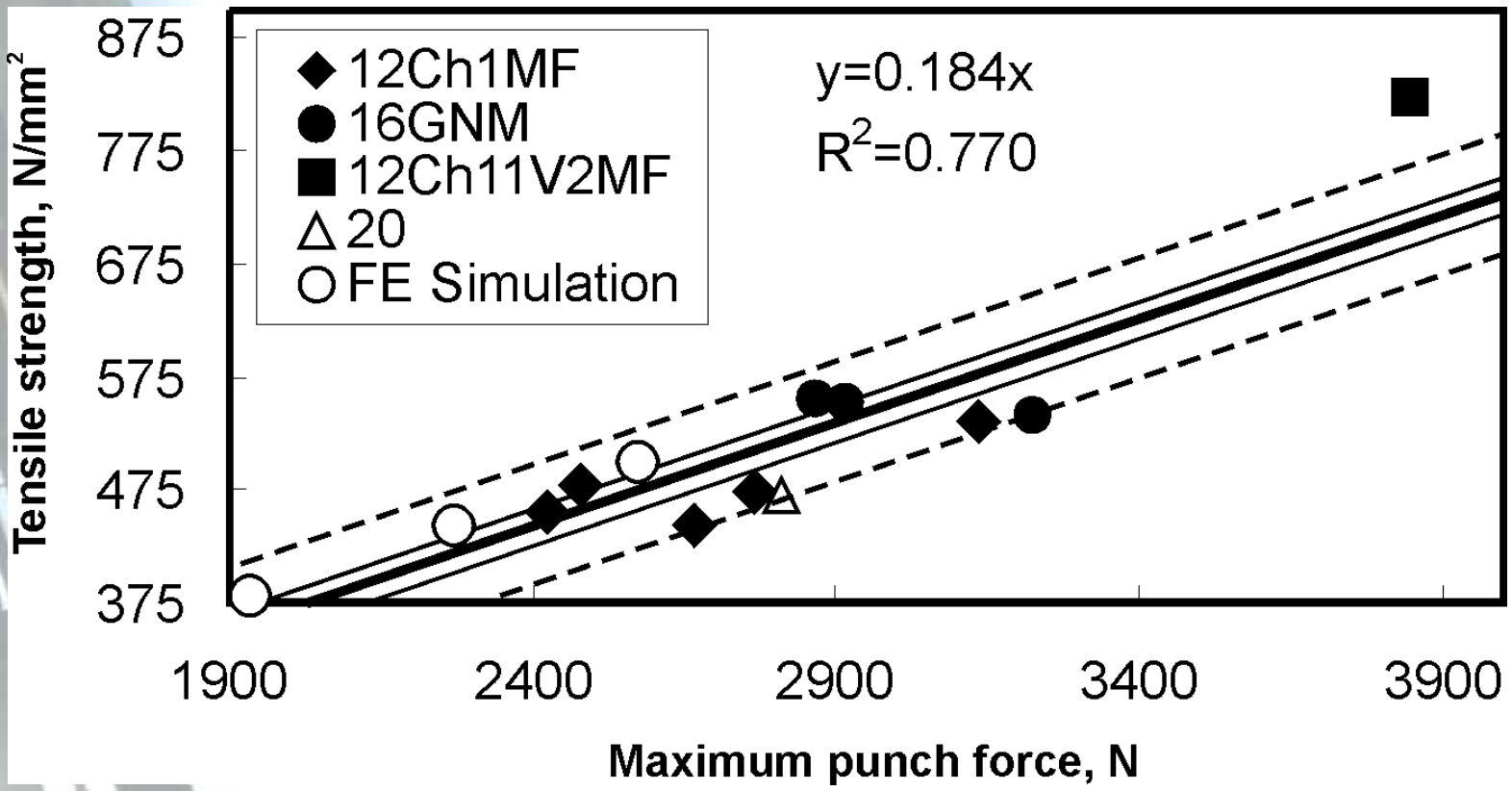
SMALL PUNCH TEST

Untypical rupture (id:3) Typical rupture (id:1 and id:2)



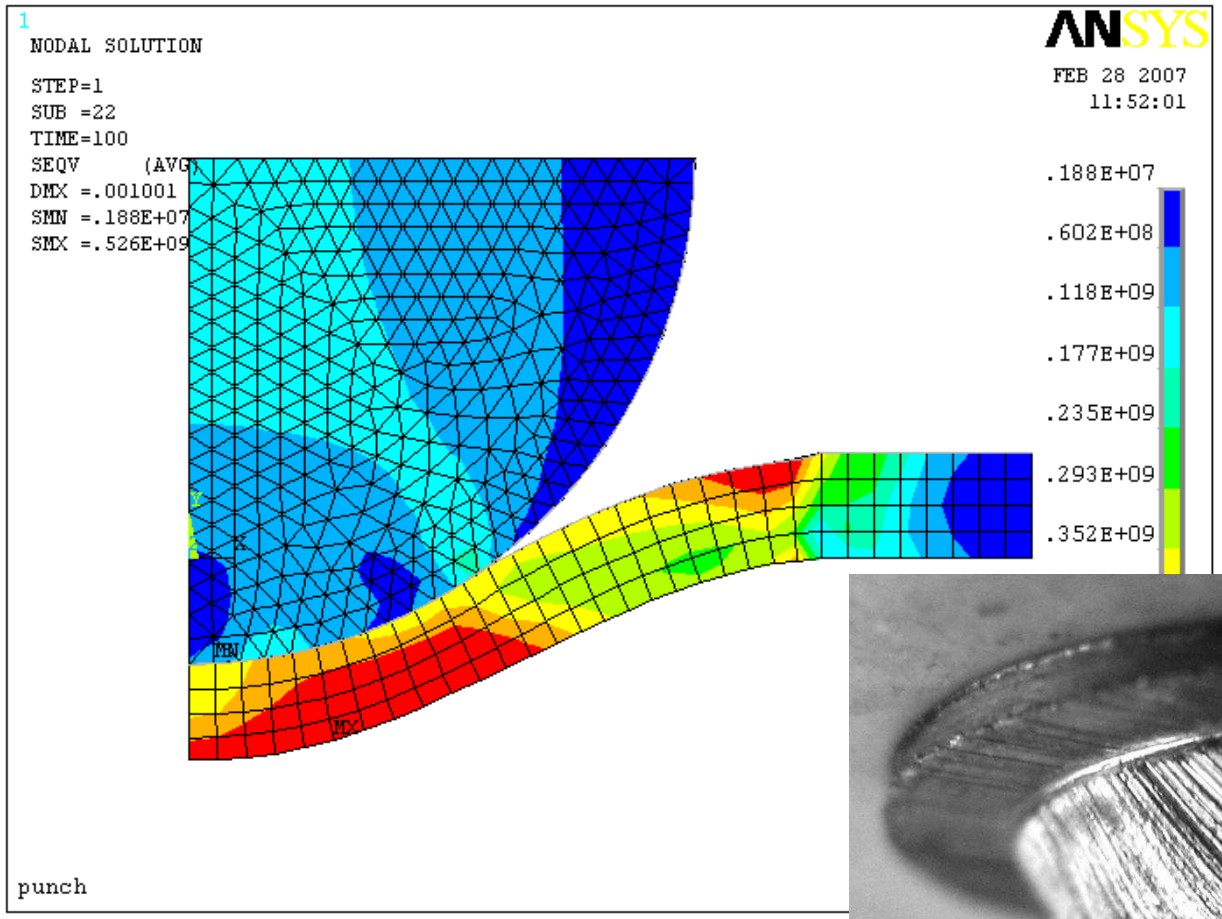
RESULTS (SPT)

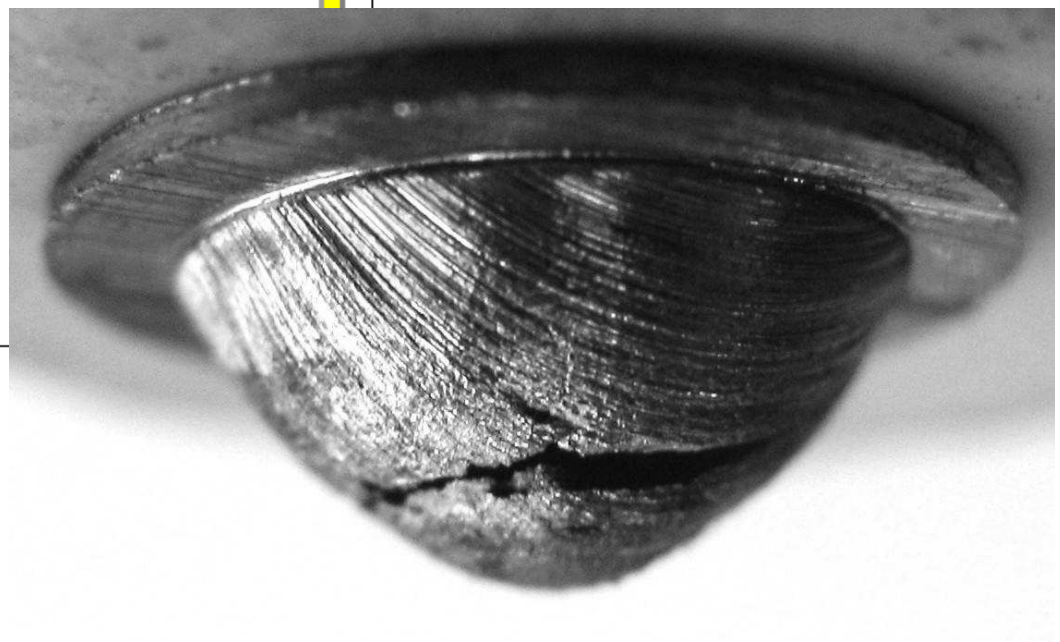
$$R_m = 0.184 \cdot F_{max} \pm 53 \text{ N/mm}^2$$



Relationship between SP maximum force and tensile strength

RESULTS (SPT)





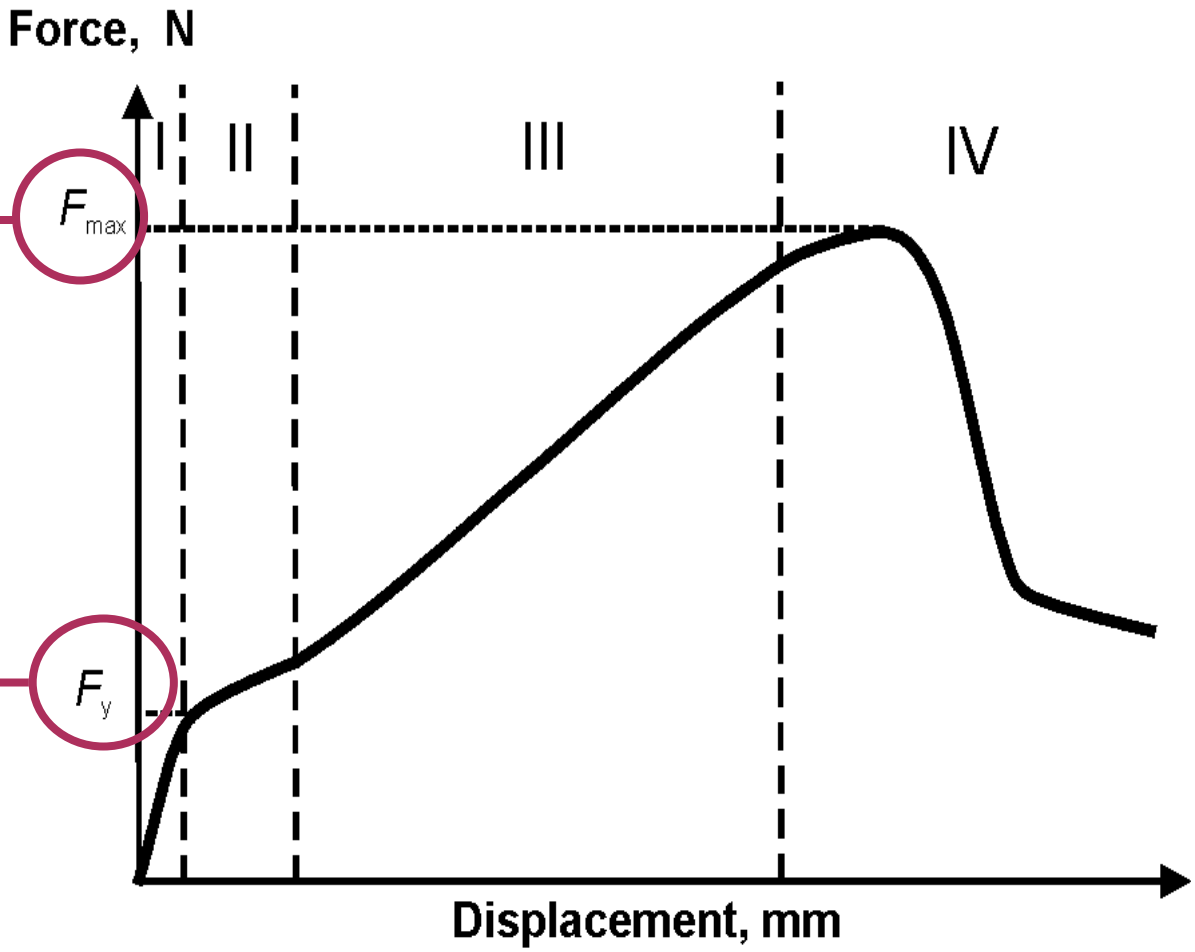
FEM at punch displacement of 1.0 mm

SMALL PUNCH TEST (SPT)

1. Brookfield D. et al.

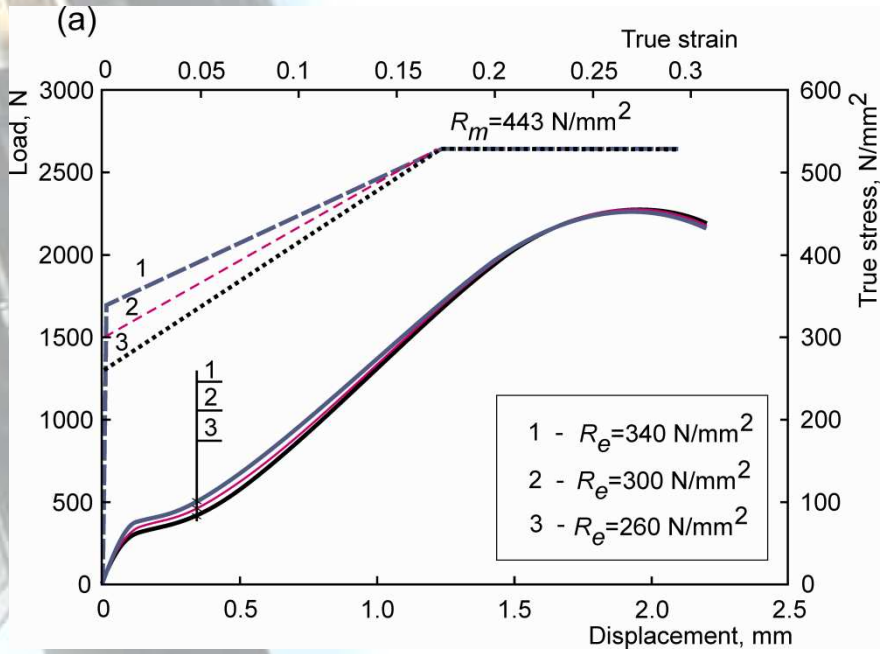
2. Fleury E. et al.

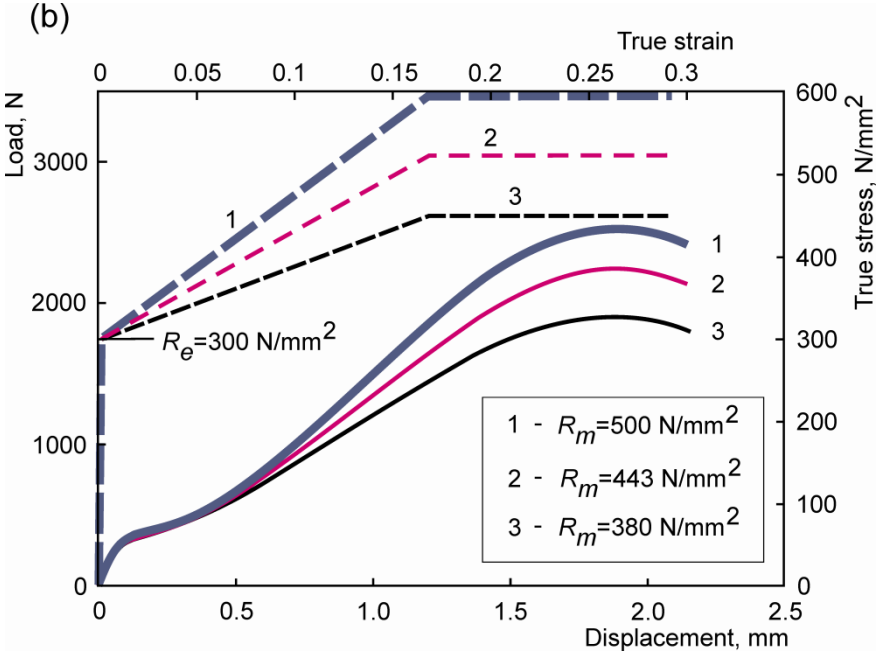
   Ruan Y. et al.



Force-displacement curve

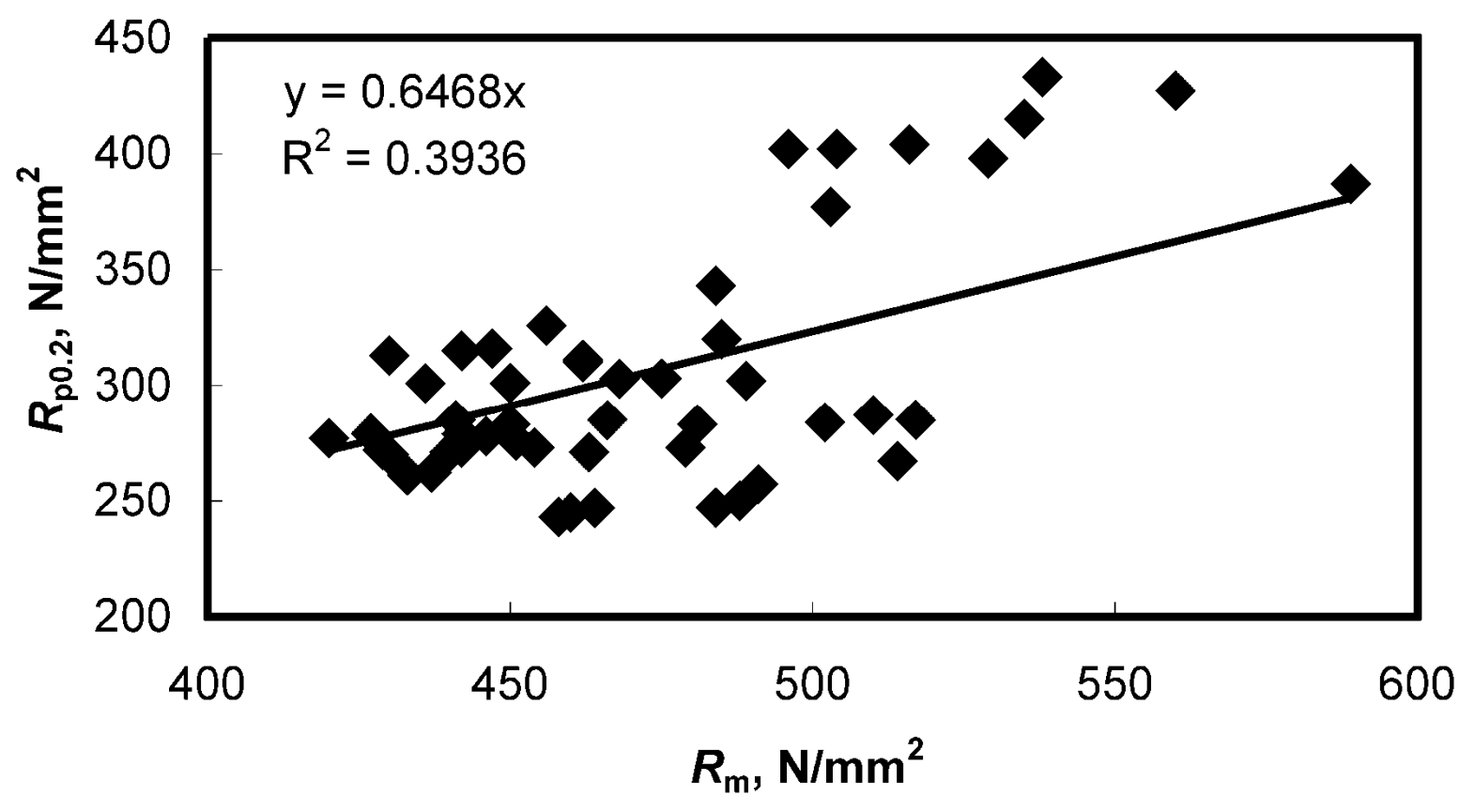
RESULTS (FEM)





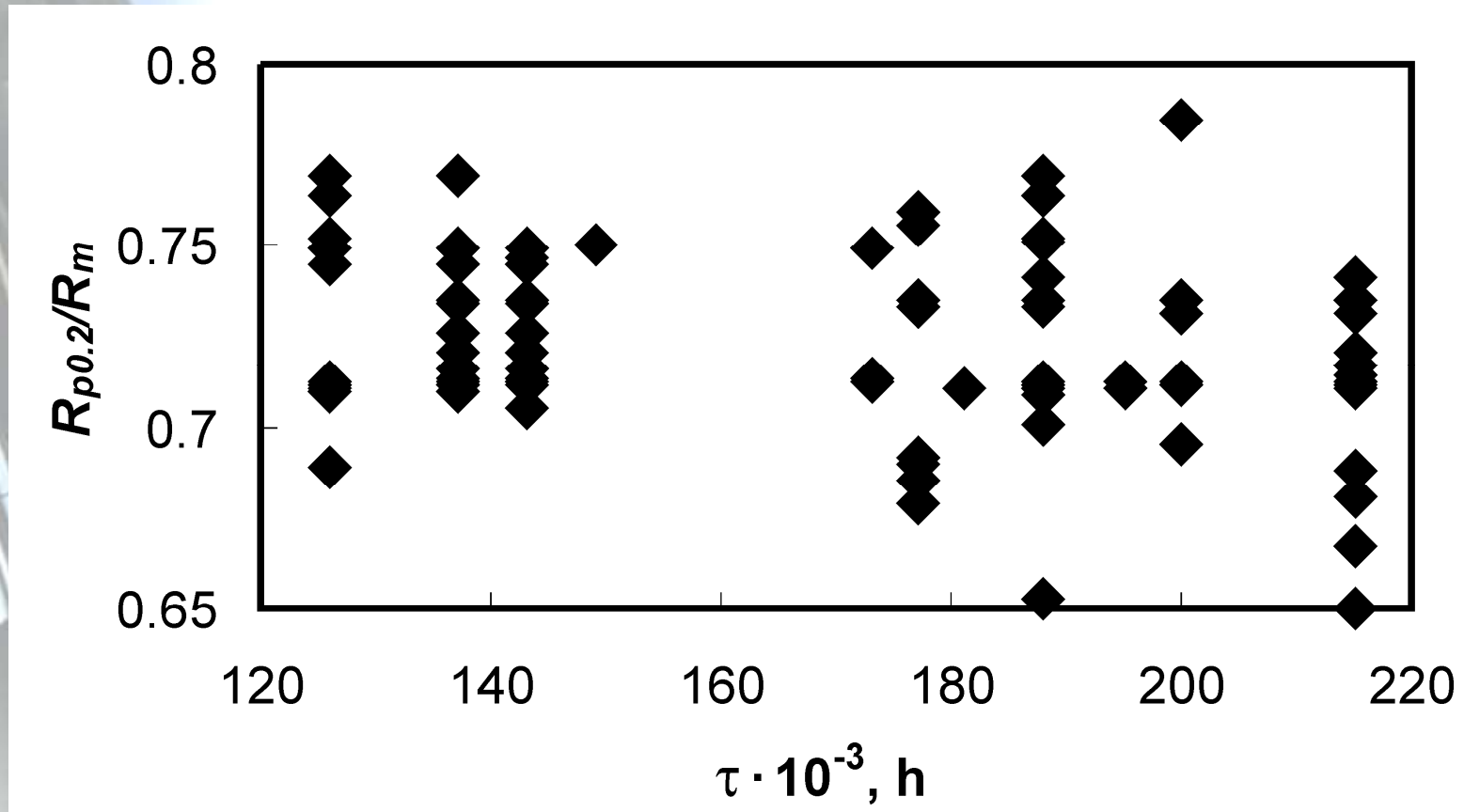
FE simulation of SP testing for materials with different tensile properties

YIELD TO TENSILE



Relationship between the yield strength and tensile strength of the steel 12Ch1MF

SERVICE TIME EFFECT



Relationship between the ratio of yield strength to tensile strength of the steel 12Ch1MF and operation time

SMALL PUNCH TEST (SPT)

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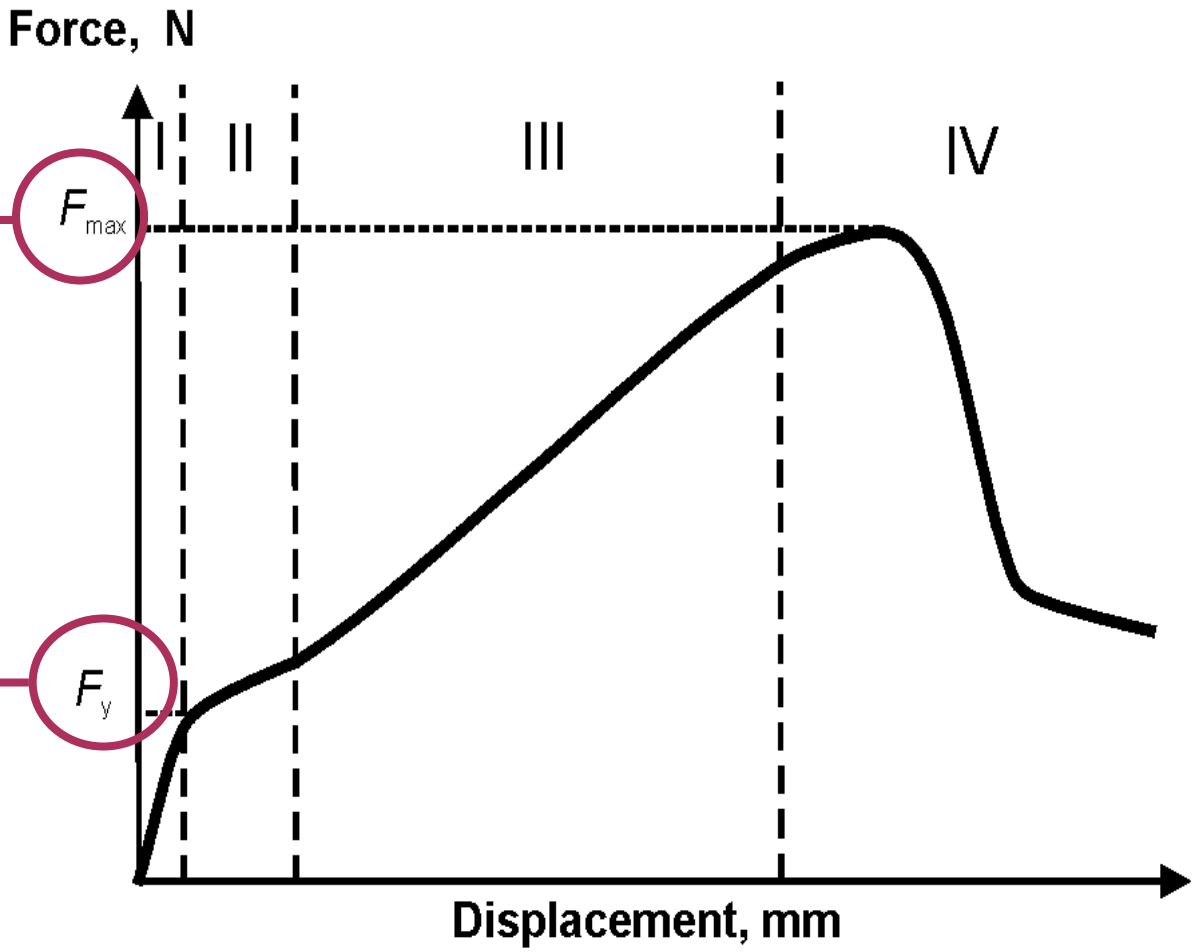
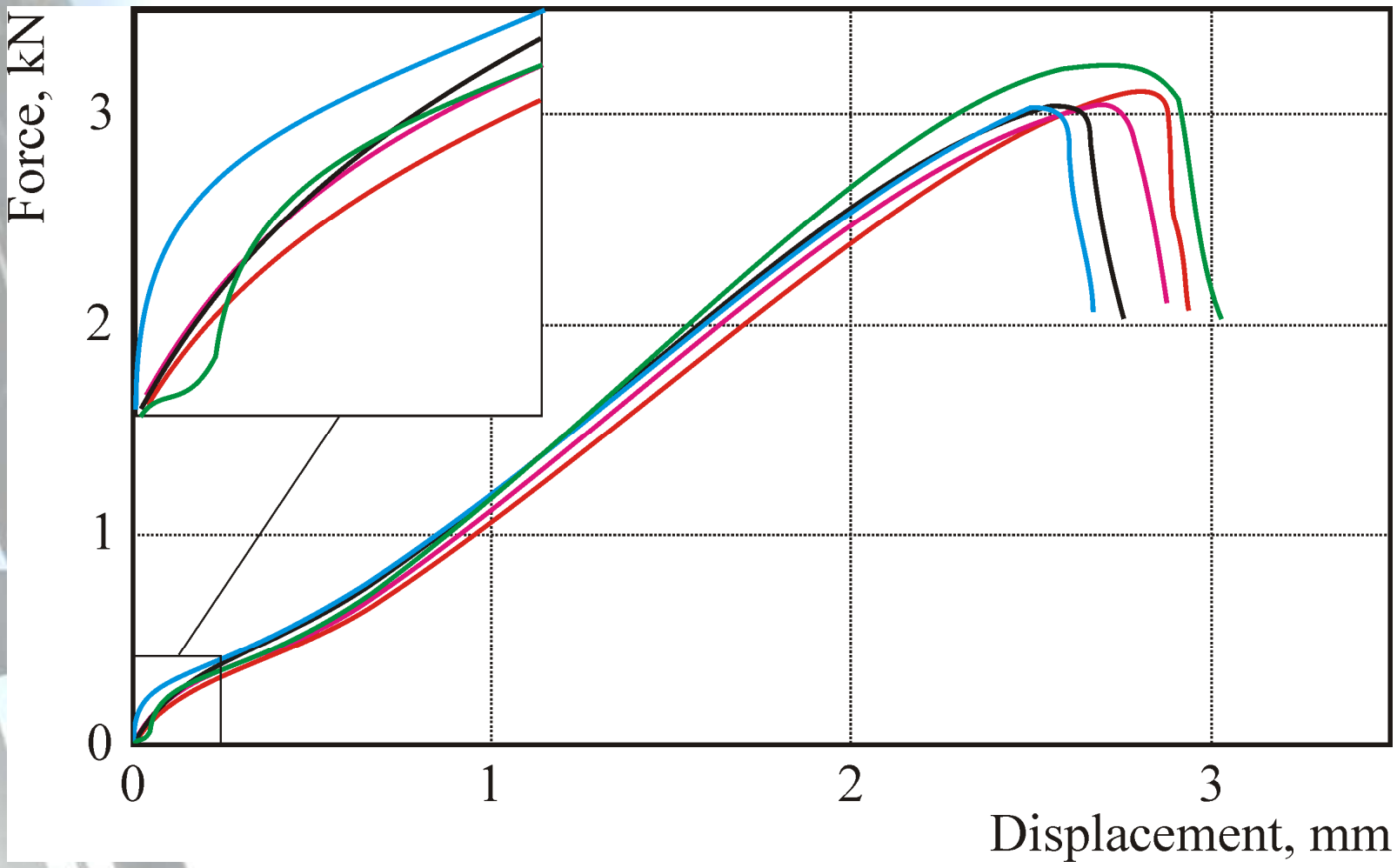
2. Fleury E. et al.

   Ruan Y. et al.



Force-displacement curve

SMALL PUNCH TEST (SPT)



Force-displacement curve

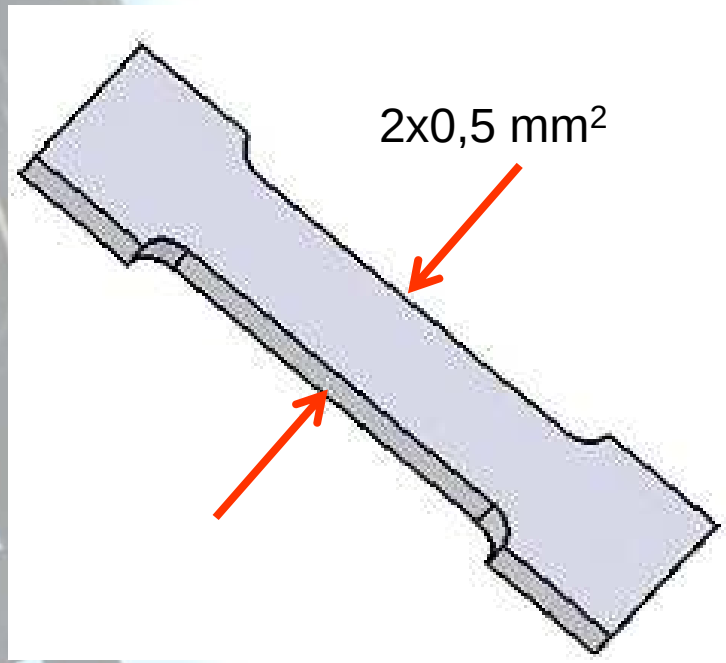
CONCLUSIONS

1. Tensile strength of the metal can be reliably obtained as a linear function of the maximum punch force determined in the small punch test.

2. The yield strength of the investigated steels cannot be reliably determined depending on the maximum punch force, but it could be correlated with elastic plastic transition force obtained from the punch force-displacement curve.

THANK YOU FOR YOUR ATTENTION!!!

TENSILE TESTING



TENSILE TESTING