

Determination of Fracture Behaviour of Structural Steels using Subsize Specimens

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Determination of Mechanical Properties of Materials by Small Punch
and other Miniature Testing Techniques

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Introduction

- **Structural steels – bcc - transition behaviour**
- **Evaluation of fracture behaviour in transition region can be provided according to ASTM E 1921 standards.**
- **Recent standard E 1921 is based on „Master curve“ concept developed by Kim Wallin.**

Master curve concept

Master curve: temperature dependence of median of fracture toughness in the transition range

$$K_{JC}(\text{med}) = 30 + 70 \exp[0,019 (T-T_0)]$$

Master curve concept (ASTM E 1921) is based on the reference temperature T_0 . This is temperature at which median of fracture toughness for 1T specimen is equal $K_{JC(\text{med})} = 100 \text{ MPa m}^{1/2}$.

You can use specimens with other thickness B_1 and after test recalculated results on 1T thickness.

Specimens

➤ For fracture toughness tests

CT, SEB etc. with dimensions normally about
 $B = 25\text{mm}$, $W = 50\text{mm}$.

Precracked Charpy specimens also can be used
 $B = 10\text{mm}$, $W = 10\text{mm}$,

Large volume of testing material !

New approaches: SUBSIZE SPECIMEN

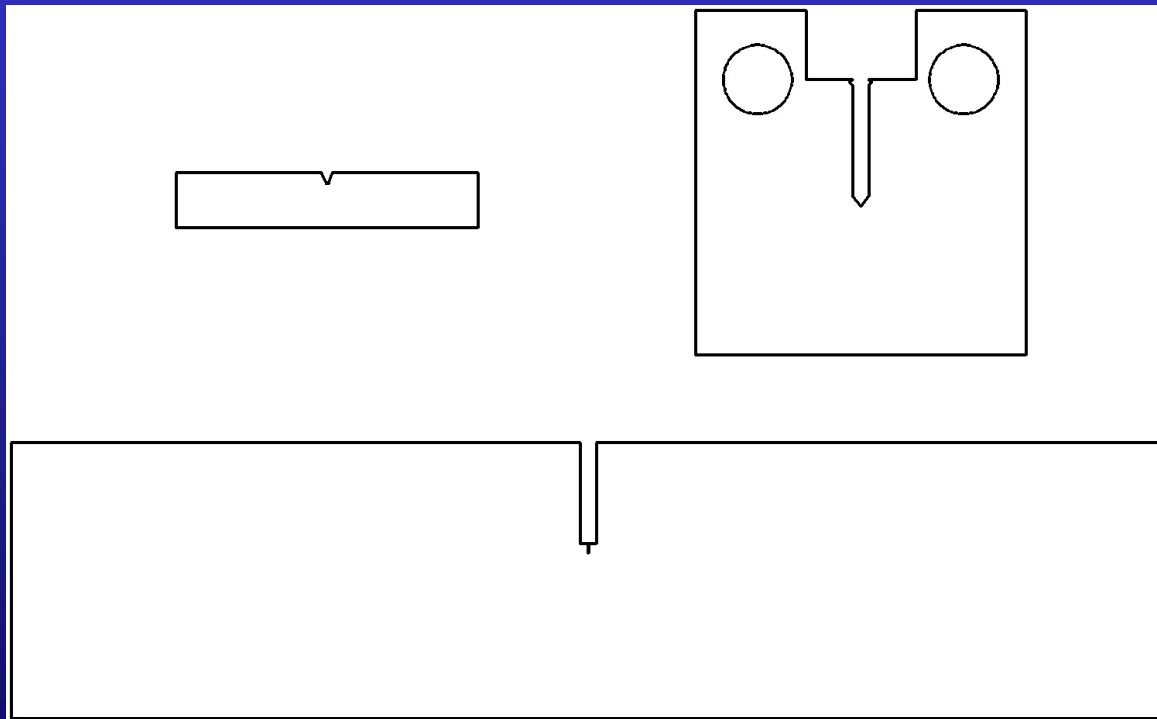
Miniaturized test techniques

- **Miniaturized Charpy specimen 3 x 4 x 27 mm (DIN 50 115)**
- **Miniaturized Charpy specimens 3 x 5 x 32 mm developed in our company several years ago**
- **Miniaturized 5 x 5 x 27 mm – can be used both for impact test as well as for fracture toughness test „1: 2 scaled Charpy“**

Specimens

Standard

Subsize



Motivation

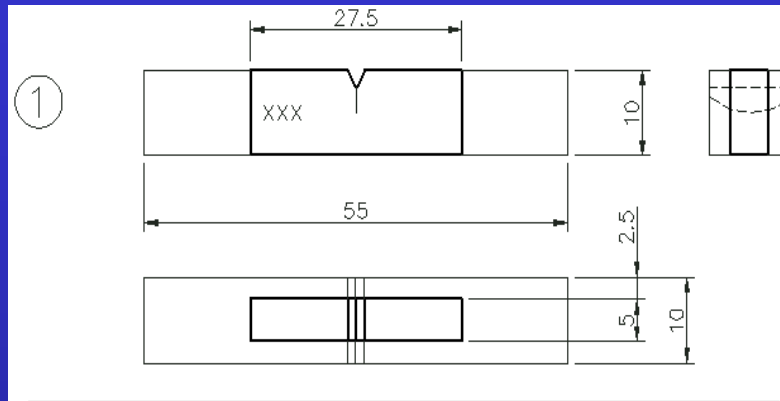
- **Verification of 1:2 scaled Charpy specimens for several structural steels**
- **Comparison obtained results with results on standard fracture toughness specimens**

Steels:

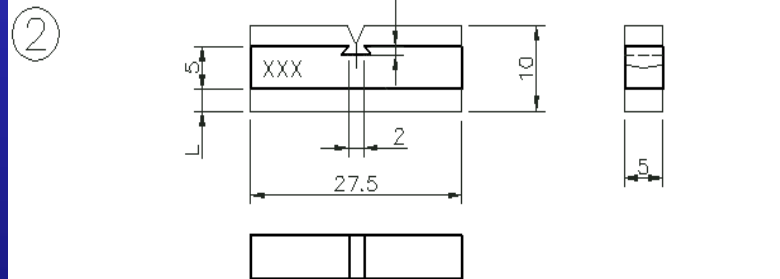
Experimental program was carried out on 3 types of structural steels:

- **steel 13 116 – C – Mn microalloyed steel made in Vítkovice, weldable, developed for applications at arctic temperatures**
- **15NiCuMoNb5 (WB 36) – structural steel for steam power application for subcreep temperatures**
- **42CrMo4 – structural steel for shafts of wind power plants rotors**

Experiments



ROZMĚR L URČÍ ZADAVATEL PRO KAŽDOU VRUBOVKU SAMOSTATNĚ



Standard Charpy specimens were manufactured.

Fatigue precrack procedure according to ASTM E 1921

fatigue crack $a_0/W \sim 0.5 K_{\max \text{ final}}$
below $18 \text{ MPa m}^{1/2}$.

1 : 2 scaled Charpy specimens were manufactured from precracked Charpy specimens

Experiments

Fracture toughness tests

three – point bending on servohydraulic test machine MTS 100 kN

- span $4 \times W$
- speed of testing 0.2 mm/min
- testing temperature ($-196 \div -130^{\circ}\text{C}$) (is necessary, due to loss of constraint, apply considerably lower testing temperature than the value of T_0)
- force versus CMOD dependence was recorded, J-integral and K_{JC} equivalent of fracture toughness were calculated

Experiments

- - all results were recalculated on 1T thickness and plotted into temperature dependencies of fracture toughness obtained on standards test specimens
- - for each type of specimen value of T_0 was calculated using multi-temperature approach.

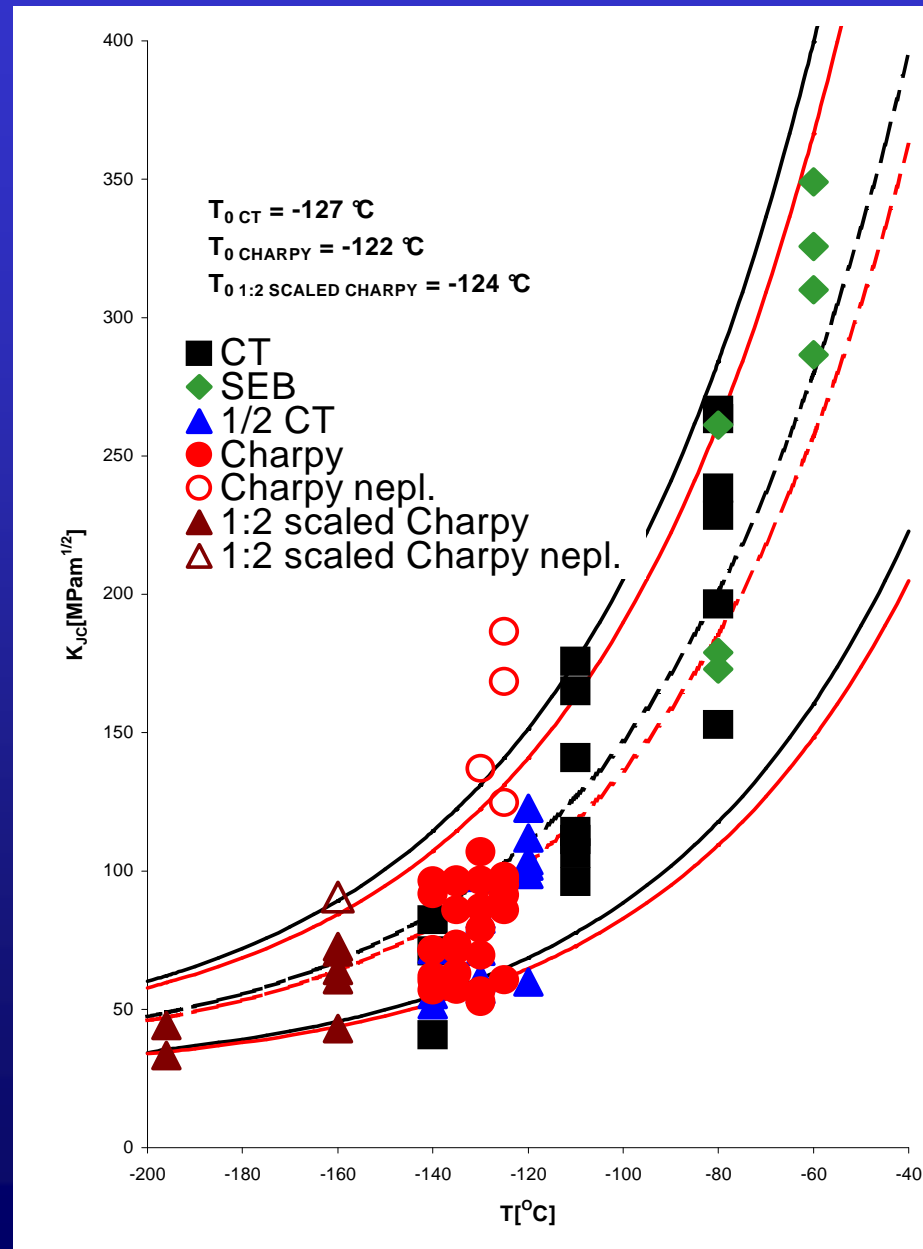
Results:

13 116

$T_{0\text{ CT}} = -127^\circ\text{C}$

$T_{0\text{ Charpy}} = -122^\circ\text{C}$

$T_{0\text{ 1:2 Charpy}} = -124^\circ\text{C}$

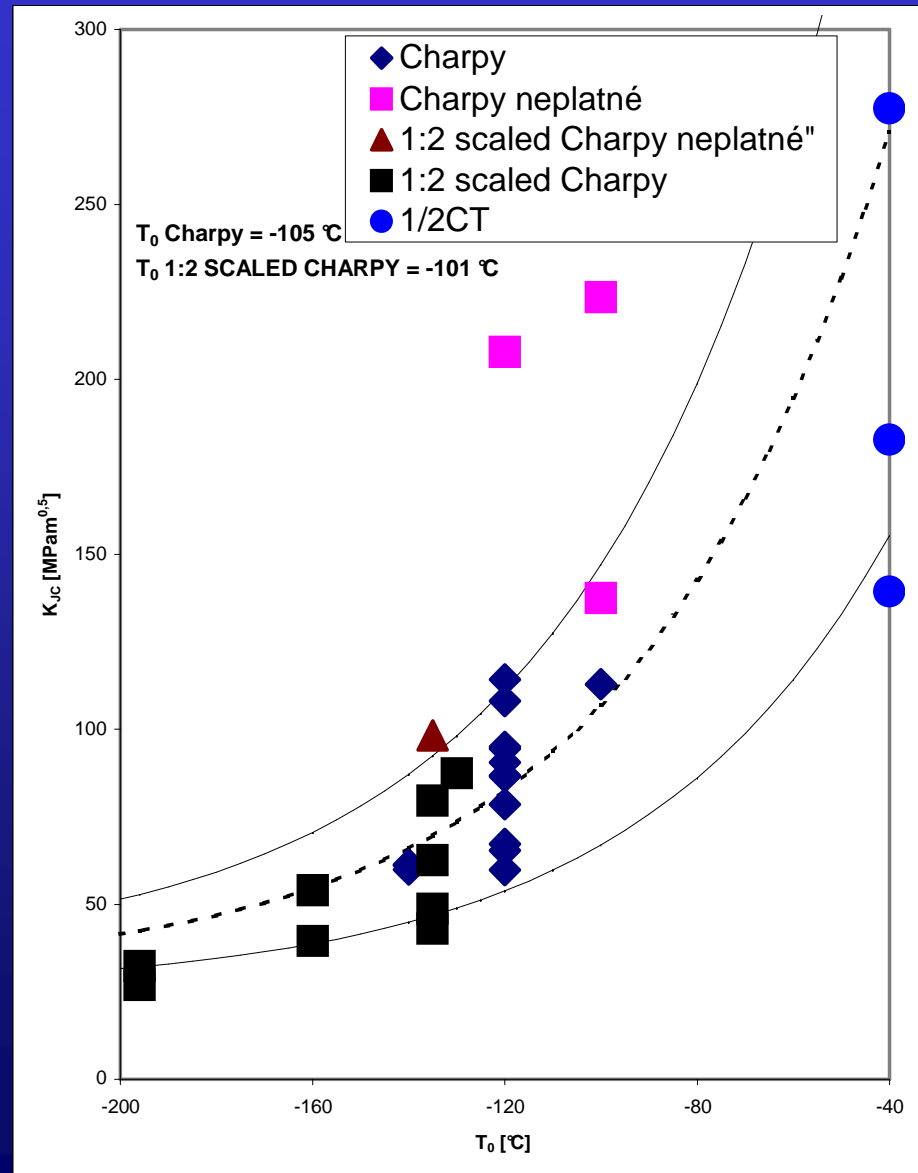


Results:

WB 36

$T_0 \text{ Charpy} = -105^\circ\text{C}$

$T_0 \text{ 1:2 Charpy} = -101^\circ\text{C}$

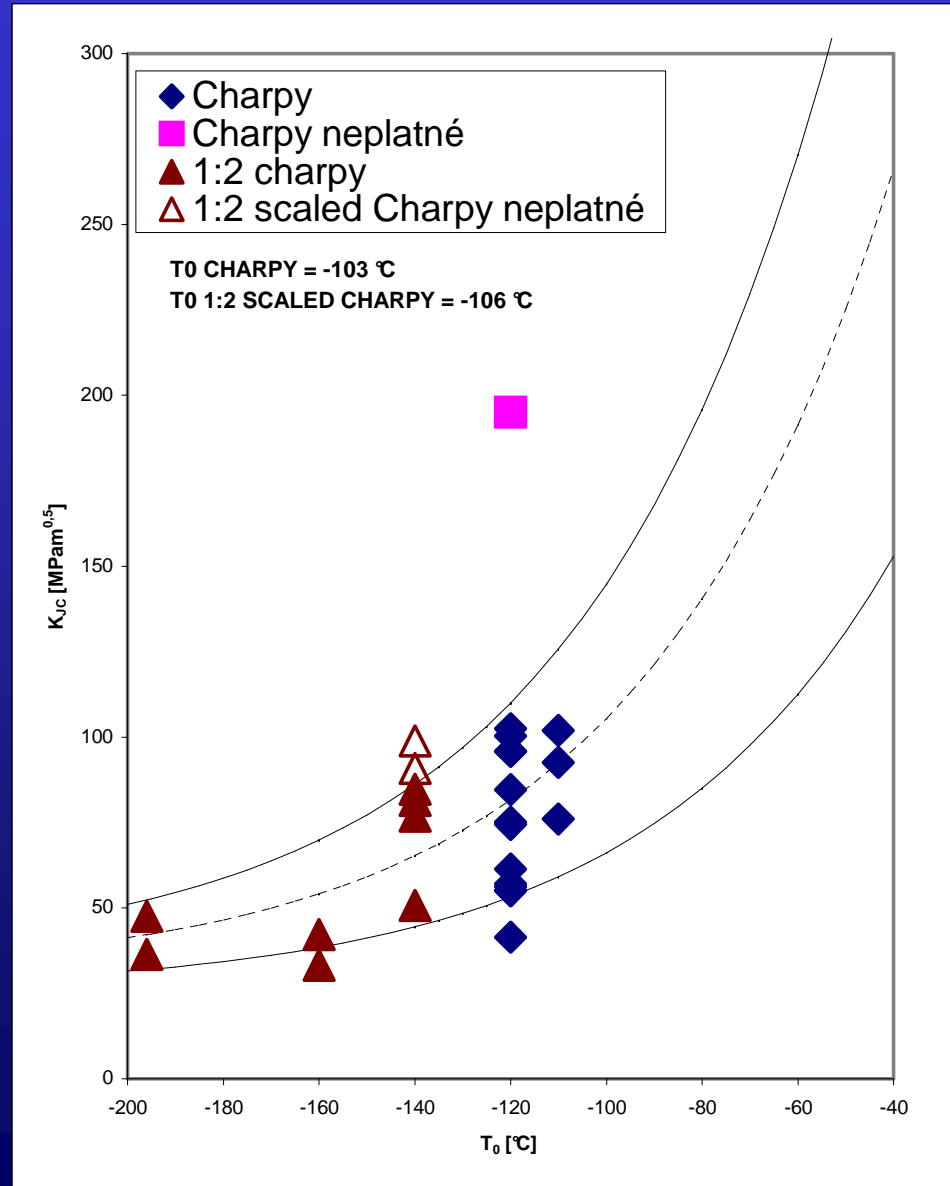


Results:

42CrMo4

$T_0 \text{ Charpy} = -103^\circ\text{C}$

$T_0 \text{ 1:2 Charpy} = -106^\circ\text{C}$



Optimization of testing temperature for 1:2 scaled Charpy specimens

Why ?

**If you test so small specimen at T_0 – not valid result
(over constraint limit or stable crack growth)**

**If you test below T_0 you can obtain strongly conservative
value of T_0**

From results

$$T_{\text{testing}} = T_0 - 35^{\circ}\text{C}$$

Summary :

- ❖ **New geometry of so called 1 : 2 scaled Charpy specimens was verified**
- ❖ **Verification was made on 3 types of structural steels covering wide range of technical applications**
- ❖ **Very good agreement was observed for all types of steel**
- ❖ **Based on the experimental results relation for calculation of correct test temperature was proposed**

Acknowledgement

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Thank you for your attention