

# ISO/TR 23602 :2005-07 (E)

## Toughness of chain steels

---

<b>Contents</b>		<b>Page</b>
Foreword.....		v
1 Scope .....		1
2 Normative references .....		1
3 Types of chain and extraction of specimens .....		2
4 Materials, chemical composition and heat-treatment.....		2
5 Tensile tests on chains .....		2
6 Conventional tensile tests on standard specimens.....		3
7 Notch impact tests.....		3
8 Fracture mechanics tests on notched chain links with slits.....		4
9 Fracture mechanics tests on notched three-point bend specimens with slits and fatigue cracks.....		6
10 Correlation between the load-bearing capacity of chain links containing slits and material toughness.....		7
11 Fracture mechanics derivation of chain links .....		7
12 Load-bearing and brittle fracture transition concept — Requirements .....		8
13 Correlation of test results with data from the literature .....		9
14 Summary.....		9
Figure 1 — Results $C_V$ tests: Standard specimen (EN 10045).....		11
Figure 2 — Load-time diagram for instrumented $C_V$ .....		13
Figure 3 — Crack arrest load as function of temperature .....		14
Figure 4 — Noncrystalline area in $C_V$ — Test.....		15
Figure 5 — Load–COD diagram for TPB specimens with fatigue crack and eroded slits material type T, $T = -40\text{ °C}$ .....		16
Figure 6 — Load–COD diagram for TPB specimens with fatigue crack and eroded slits material grade VH, $T = -40\text{ °C}$ .....		17
Figure 7 — Comparison of pre-cracked and eroded chain link material grade VH, $T = -40\text{ °C}$ .....		18
Figure 8 —Chain link specimen .....		19
Figure 9 — Clip gauge fixed in chain link.....		20
Figure 10 — Calibration of clip gauge for COD measurement.....		21
Figure 11 — Test specimen at $-40\text{ °C}$ , three links.....		21
Figure 12 — Effect of slit size on loadability of chain, $T = -40\text{ °C}$ .....		22
Figure 13 — Load–COD diagram for tension tests on chains with eroded slit, $T = -40\text{ °C}$ , $ald = 0,22$ .....		23
Figure 14 — Load–COD diagram for tension tests on chains with eroded slit, $T = -40\text{ °C}$ , $ald = 0,43$ .....		24
Figure 15 — Load–COD diagram for tension tests on chains with eroded slit, $T = -40\text{ °C}$ , $ald = 0,64$ .....		25
Figure 16 — Stable crack growth chain Type T, $ald = 0,22$ — Marked by heat tinting .....		26
Figure 17 — Effect of slit size on absorbed energy of chains, $T = -40\text{ °C}$ .....		27

Figure 18 — Fracture mechanics tests on TPB specimens.....	28
Figure 19 — Fracture mechanics concepts.....	29
Figure 20 — Fracture toughness values for TPB specimens with eroded slits, $T = -40\text{ }^{\circ}\text{C}$ , $alw = 0,5$ .....	30
Figure 21 — R-curves material Type T, $T = -40\text{ }^{\circ}\text{C}$ , $alw = 0,4$ .....	31
Figure 22 — R-curves material Type T, $T = -40\text{ }^{\circ}\text{C}$ , $alw = 0,4$ .....	32
Figure 23 — Nominal fracture stress in chain link, correlated with fracture mechanics properties.....	33
Figure 24 — Nominal fracture stress in chain link correlated with fracture mechanics properties.....	34
Figure 25 — Correlation of fracture load and $C_V$ toughness .....	35
Figure 26 — Correlation nominal fracture stress of chain and $C_V$ toughness.....	36
Figure 27 — Finite element analysis of chain links with eroded slit, $ald = 0$ .....	37
Figure 28 — Finite element analysis of chain links with eroded slit, $ald = 0,22$ .....	37
Figure 29 — Finite element analysis of chain links with eroded slit, $ald = 0,64$ .....	38
Figure 30 — Nominal stresses in cracked chain link .....	39
Figure 31 — Correction factor for long bending bars <sup>[5]</sup> .....	40
Figure 32 — Stress intensity factor for long bending bars .....	41
Figure 33 — Safety relations between requirement and service conditions .....	42
Figure 34 — Nominal fracture stress in chain link, correlated with fracture mechanics properties.....	43
Figure 35 — Correlation nominal fracture stress of chain and $C_V$ toughness.....	44
Figure 36 — Correlation of fracture and $C_V$ toughness pre-cracked TPB specimens .....	45
Table 1 — Chemical composition of the chain steels .....	46
Table 2 — Tensile test results on chain specimens (5 links) .....	46
Table 3 — Tensile test results on standard specimens (EN 10002, B6*30) $T = -40\text{ }^{\circ}\text{C}$ .....	46
Table 4 — Results of $C_V$ tests.....	47
Table 5 — Crack arrest loads of $C_V$ tests .....	47
Table 6 — Noncrystalline area of $C_V$ specimens .....	47
Table 7 — Transition behaviour of chain materials.....	47
Table 8 — Maximum loads of chain-tests at $-40\text{ }^{\circ}\text{C}$ .....	48
Table 9 — Maximum displacement for chain tests, $T = -40\text{ }^{\circ}\text{C}$ .....	48
Table 10 — Absorbed energy of the chain tests, $T = -40\text{ }^{\circ}\text{C}$ .....	48
Table 11 — Evaluation of fracture mechanics test on TPB specimens .....	49
Table 12 — Fracture mechanics tests on TPB specimens with eroded slits.....	49
Table 13 — Fracture mechanics tests on TPB specimens with fatigue cracks, $T = -40\text{ }^{\circ}\text{C}$ .....	49
Table 14 — R curves data material Type T .....	50
Table 15 — Calculation of $K_Q$ values for chain grade VH .....	50
Bibliography .....	51