Article:

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Table 3: Situations of practical interest used to investigate the way the Total Fatigue Damage, D_{tot}, increases over time when it is estimated according to the proposed methodology.

Figure 1: Pit in the wall of a pipe and its schematisation through a hemispherical and hyperbolic notch (a); pit depth vs. time according to Rajani's exponential law [24] (b); fatigue strength reduction factor vs. pit tip radius estimated for grey cast iron with flake graphite according to Heywood [38] (c).

Figure 2: Structural schematisations adopted to perform the stress analysis.

Figure 3: Uniaxial (a) and torsional (b) fully-reversed plain and notch fatigue curves.

Figure 4: In-field use of the MWCM.

Figure 5: Proposed methodology to estimate the fatigue damage, D_{y-i}, associated with the i-th year of service.

Figure 6: Adopted load spectra summarizing the number of significant events per day.

Figure 7: Total Fatigue Damage evolution over time for the situations described in Table 3.

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Tables

Case	$p_{i,a}$ [MPa]	R_i	$p_{e,a}/p_{i,a}$	R_e	ϕ_p [°]	f_i/f_e	σ_b [MPa]	σ_{ax} [MPa]	τ_t [MPa]	FDI @ r_i [%]	FDI @ r_e [%]	Type of Fatigue Analysis
Reference	6	0.1								*0.0*	24.0	CA
	6	0.1	1	0.1	0	1				267.2	267.2	CA
	6	0.1	1	0.1	0	10				*-1.5*	5.0	VA
	6	0.1	1	0.1	0	100				*11.1*	17.6	VA
	6	0.1	1	0.1	0	0.1				*-1.5*	5.0	VA
	6	0.1	1	0.1	0	0.01				*11.1*	17.6	VA
	6	0.1	2	0.1	0	1				*40.6*	58.7	CA
	6	0.1	2	0.1	0	10				*-18.6*	-8.5	VA
A	6	0.1	2	0.1	0	100				*-6.1*	4.0	VA
	6	0.1	2	0.1	0	0.1				*-19.1*	-8.9	VA
	6	0.1	2	0.1	0	0.01				*-9.5*	1.7	VA
	6	0.1	0.5	0.1	0	1				*87.5*	103.4	CA
	6	0.1	0.5	0.1	0	10				*7.4*	3.0	VA
	6	0.1	0.5	0.1	0	100				*19.0*	15.2	VA
	6	0.1	0.5	0.1	0	0.1				*7.8*	3.4	VA
	6	0.1	0.5	0.1	0	0.01				*20.2*	15.7	VA
	6	0.1	1	0.1	90	1				*10.8*	20.7	CA
	6	0.1	1	0.1	90	10				*-1.5*	5.0	VA
	6	0.1	1	0.1	90	0.1				*-1.1*	5.5	VA
	6	0.1	2	0.1	90	1				*-12.8*	-0.7	CA
B	6	0.1	2	0.1	90	10				*-18.7*	-8.6	VA
	6	0.1	2	0.1	90	0.1				*-18.9*	-8.7	VA
	6	0.1	0.5	0.1	90	1				*18.5*	17.7	CA
	6	0.1	0.5	0.1	90	10				*7.4*	2.9	VA
	6	0.1	0.5	0.1	90	0.1				*8.5*	2.9	VA
	6	0.1					50			0.0	24.0	CA
C	6	0.1					120			0.0	24.0	CA
	6	0.1					-50			0.0	24.0	CA
	6	0.1					-120			0.0	24.0	CA
	6	0.1						50		0.0	24.0	CA
D	6	0.1						120		0.0	24.0	CA
	6	0.1						-50		0.0	24.0	CA
	6	0.1						-120		0.0	24.0	CA
E	6	0.1							50	0.0	24.0	CA
	6	0.1							120	0.0	24.0	CA
	6	0.1	1	0.1	0	100	50	50	50	11.1	17.6	VA
	6	0.1	1	0.1	0	0.01	50	50	50	*11.1*	*17.6*	VA
F	6	0.1	2	0.1	0	100	50	50	50	*-6.1*	*4.0*	VA
	6	0.1	2	0.1	0	0.01	50	50	50	*-9.5*	*1.7*	VA
	6	0.1	0.5	0.1	0	100	50	50	50	19.0	15.2	VA
	6	0.1	0.5	0.1	0	0.01	50	50	50	20.2	15.7	VA

Table 1: Results of the sensitivity analysis in the absence of pitting (CA=constant amplitude solution; VA=variable amplitude solution). An FDI index equal to 0% indicates a fatigue situation equivalent to the reference case, a negative index indicates a more damaging case and a positive index a less damaging case. N.B. Normal in-service internal pressure is typically in the range 0.35-1 MPa, so that p_i was intentionally taken equal to 6 MPa to make the sensitivity analysis much easier to be interpreted.

Case	$p_{i,a}$ *[MPa]*	R_i	$p_{e,a}/p_{i,a}$	R_e	ϕ_p *[°]*	f_i/f_e	**FDI @ r_e** *[%]*	**Type of Fatigue Analysis**
G	6	0.1	1	0.1	0	100	-18.9	VA
	6	0.1	1	0.1	0	1	129.1	CA
	6	0.1	1	0.1	90	1	-26.2	CA
	6	0.1	1	0.1	0	0.01	*-18.9*	VA
	6	0.1	2	0.1	0	100	*-26.6*	VA
	6	0.1	2	0.1	0	1	*-0.1*	CA
	6	0.1	2	0.1	90	1	*-39.3*	CA
	6	0.1	2	0.1	0	0.01	*-35.3*	VA
	6	0.1	0.5	0.1	0	100	-19.7	VA
	6	0.1	0.5	0.1	0	1	24.2	CA
	6	0.1	0.5	0.1	90	1	-23.6	CA
	6	0.1	0.5	0.1	0	0.01	-14.9	VA

Table 2: Results of the sensitivity analysis in the presence of pitting (CA=constant amplitude solution; VA=variable amplitude solution). An FDI index equal to 0% indicates a fatigue situation equivalent to the reference case, a negative index indicates a more damaging case and a positive index a less damaging case. N.B. Normal in-service internal pressure is typically in the range 0.35-1 MPa, so that pi was intentionally taken equal to 6 MPa to make the sensitivity analysis much easier to be interpreted.

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	Units	**Case A**	**Case B**	**Case C**	**Case D**	**Case E**	**Case F**	**Case G**	**Case H**	**Case I**	**Case K**
Nominal Size		6" Class A	6" Class A	6" Class A	6" Class A	6" Class A	6" Class A	3" Class A	3" Class A	15" Class A	15" Class A
$\mathbf{D_e}$	*[mm]*	177.3	177.3	177.3	177.3	177.3	177.3	*95.5*	*95.5*	413.0	413.0
t	*[mm]*	10.9	10.9	10.9	10.9	10.9	10.9	*9.7*	*9.7*	15.0	15.0
a	*[mm/year]*	0.021	0.021	0.021	0.0336	0.021	0.021	0.021	0.0336	0.021	0.0336
k	*[mm]*	9.75	9.75	9.75	15.6	9.75	9.75	9.75	15.6	9.75	15.6
c	*[year^{-1}]*	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
Pit's Geometry		Hyperbolic	Hemispherical	Hyperbolic	Hyperbolic	Hyperbolic	Hyperbolic	Hyperbolic	Hyperbolic	Hyperbolic	Hyperbolic
$\mathbf{K_t}$		3.4	2.23	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
$\mathbf{p_{i,max}}$	*[MPa]*	1.8	1.8	1.8	1.8	1	1	1.8	1	1.8	1
$\mathbf{R_i}$		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$\mathbf{p_i(t)}$ **Spectrum**		p_i_CUS	p_i_CUS	p_i_CDS	p_i_CDS	p_i_CUS	p_i_CUS	p_i_CUS	p_i_CUS	p_i_CUS	p_i_CUS
$\mathbf{p_{e,max}}$	*[MPa]*	0.5	0.5	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5
$\mathbf{R_e}$		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$\mathbf{p_e(t)}$ **Spectrum**		Road_SP	Road_SP	Road_SP	Road_SP	Road_SP	Road_SP	Road_SP	Road_SP	Road_SP	Road_SP

Table 3: Situations of practical interest used to investigate the way the Total Fatigue Damage, D_{tot}, increases over time when it is estimated according to the proposed methodology.

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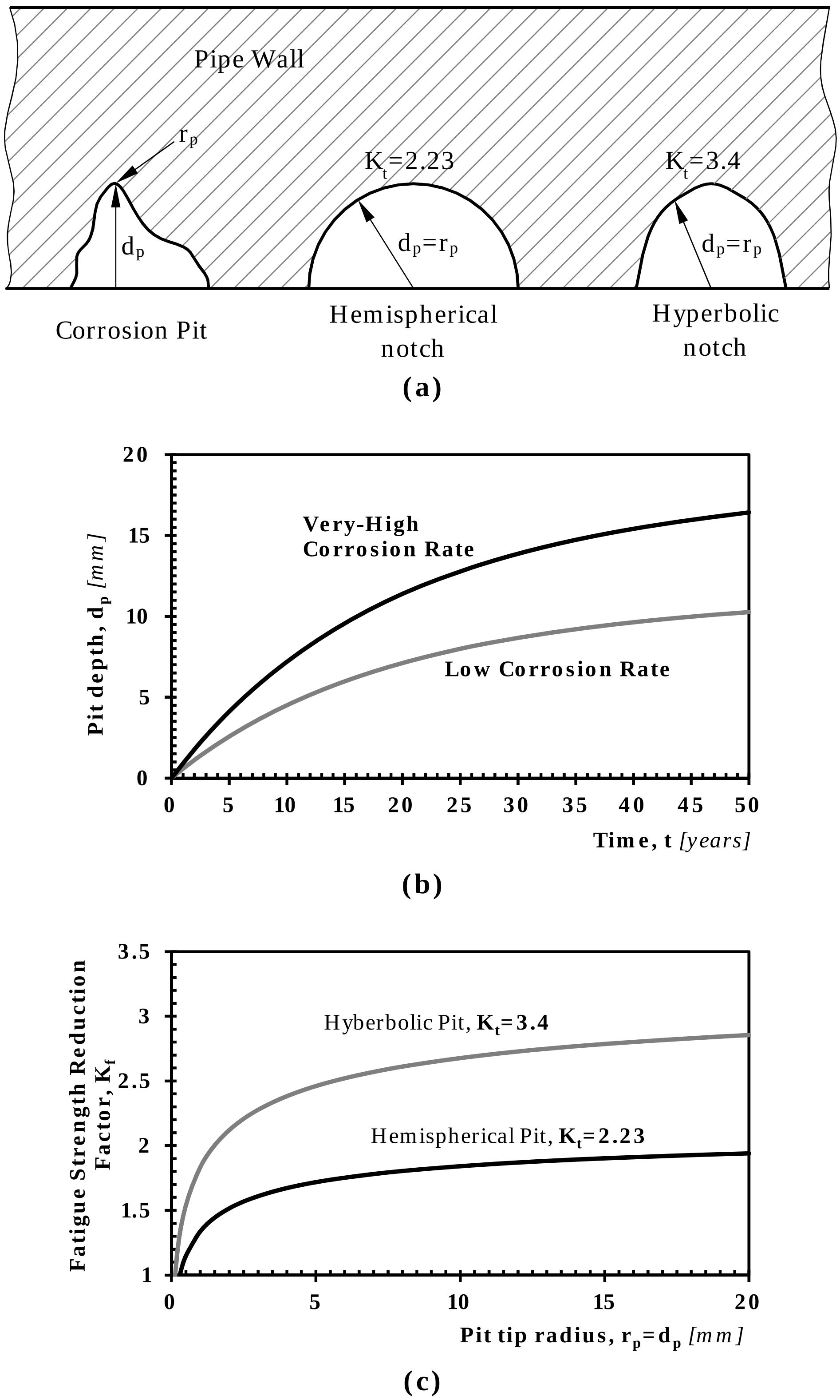
Figures



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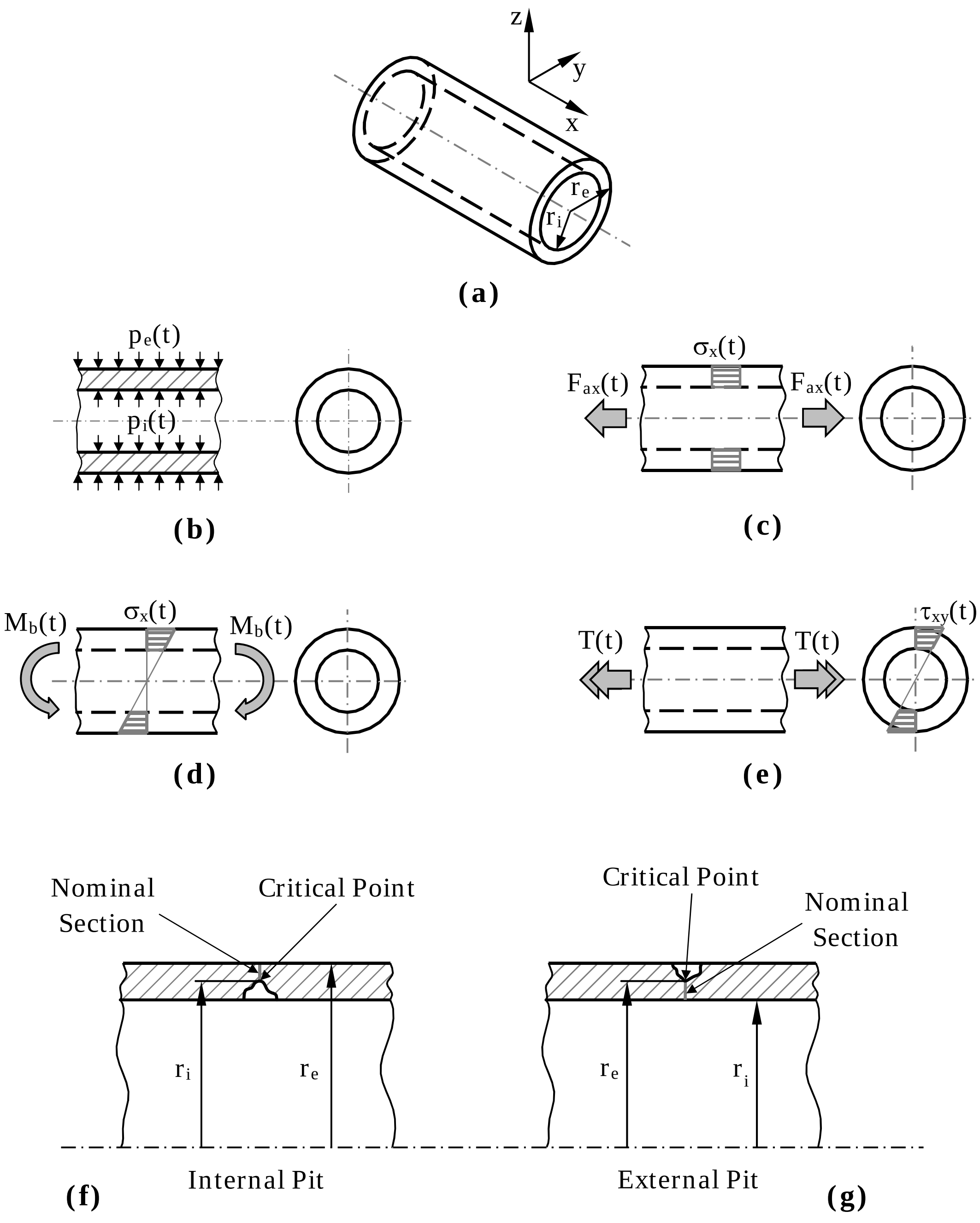

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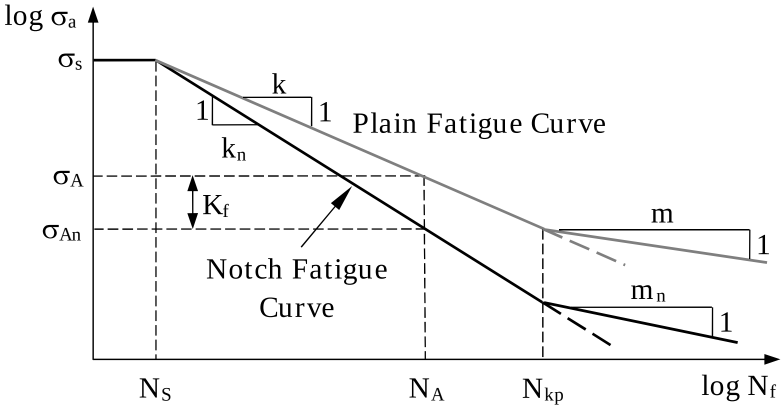
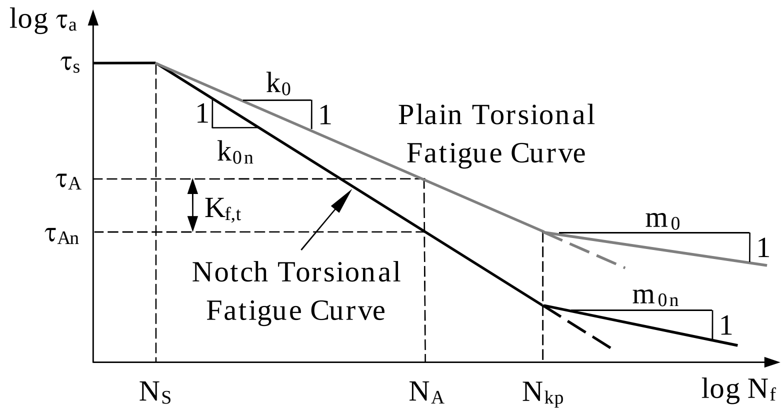


(a)



(b)

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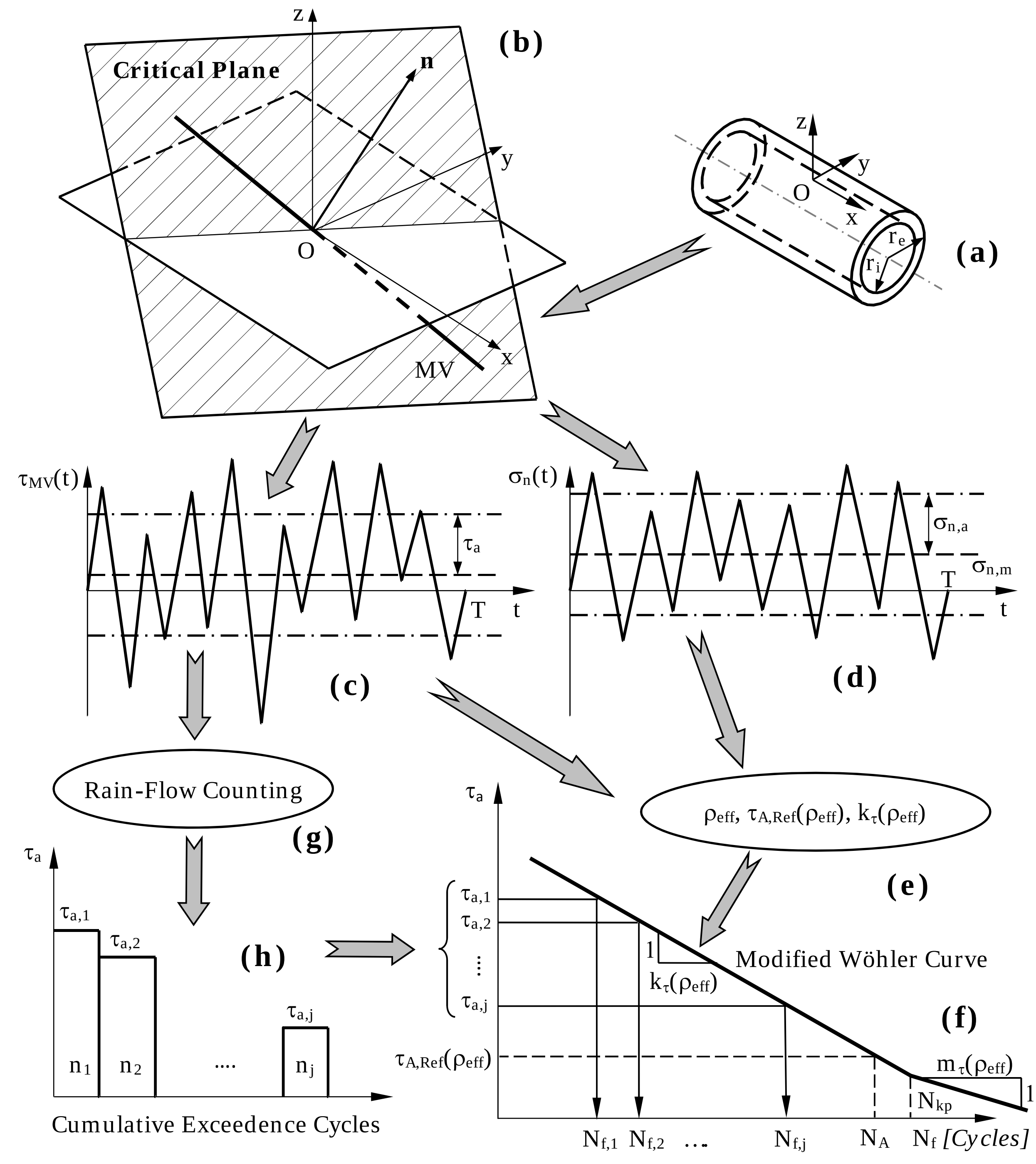

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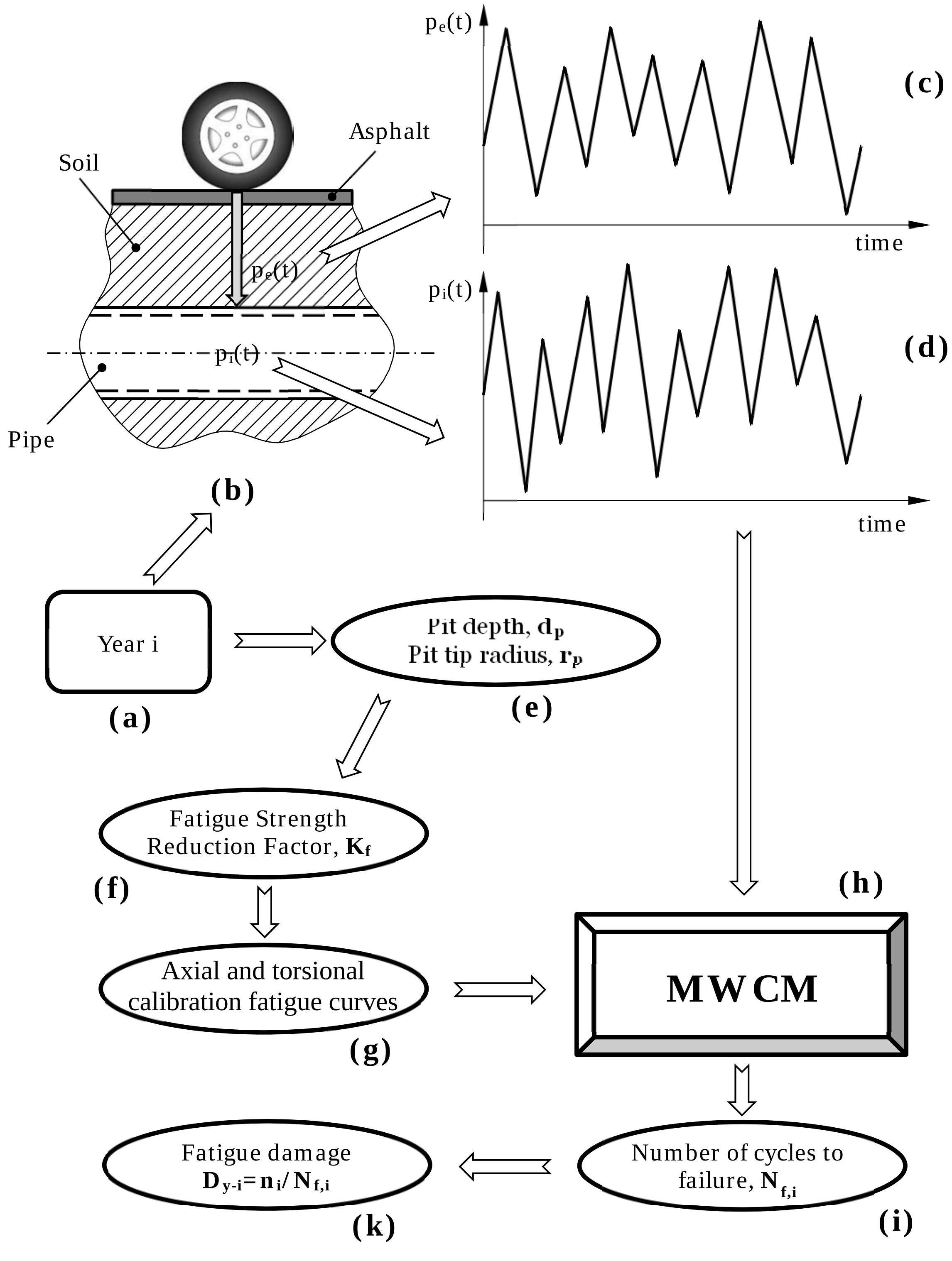

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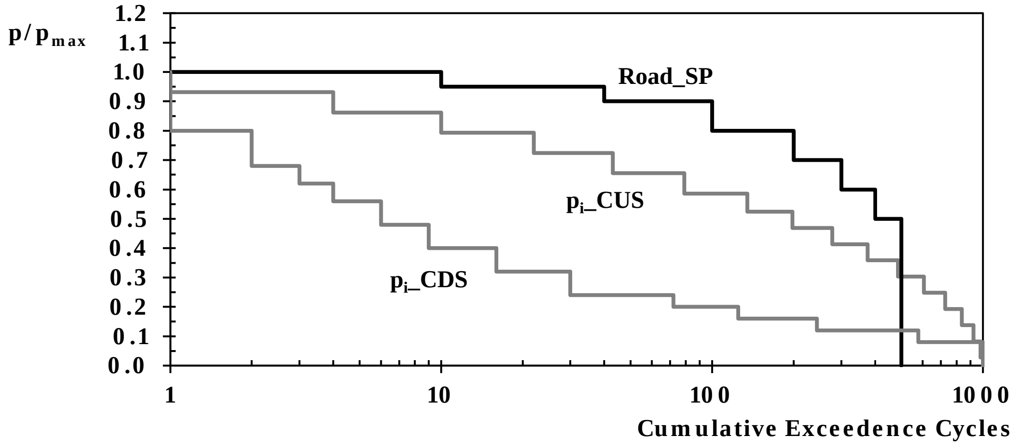

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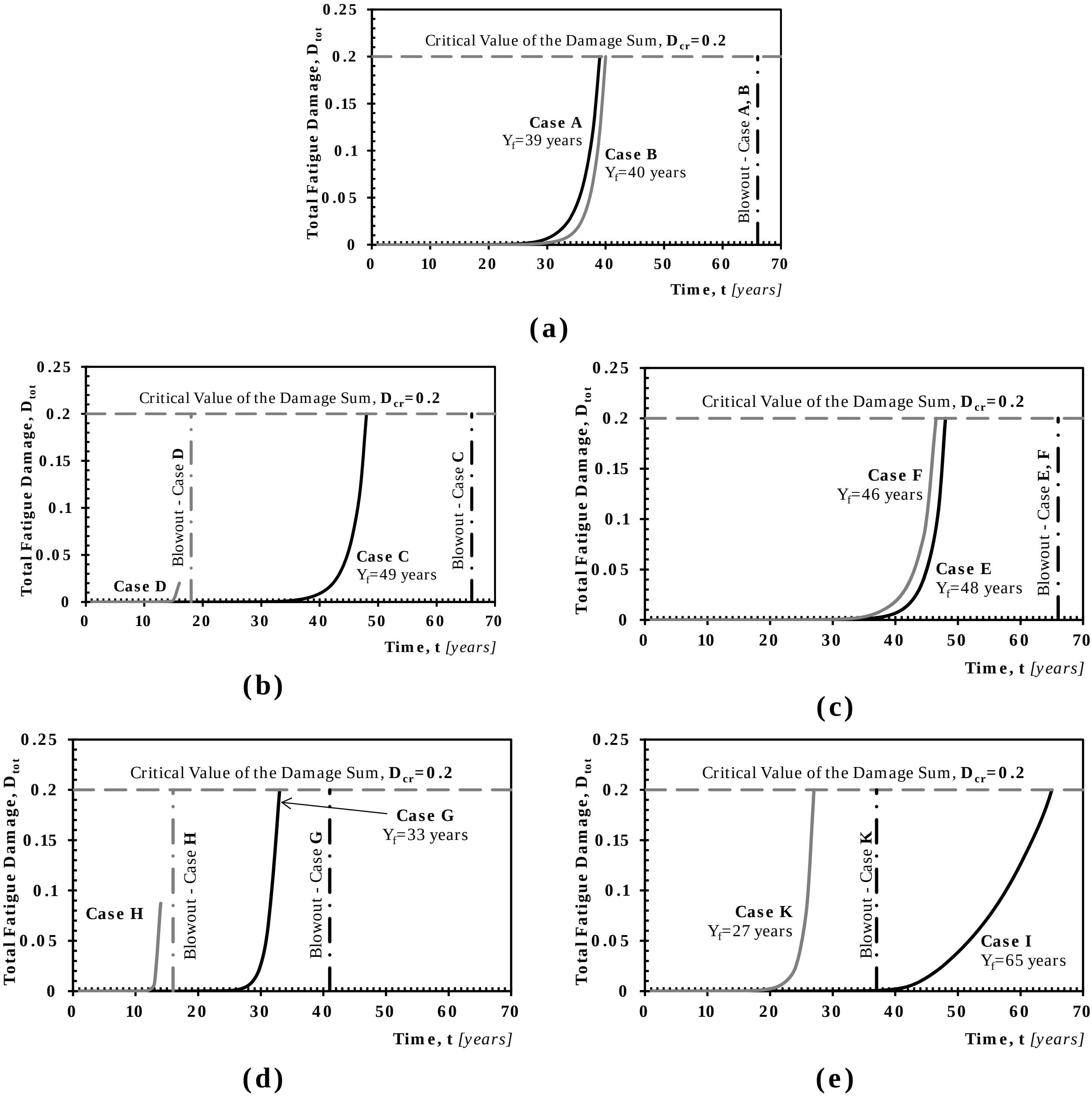

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