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## LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviation/Symbol	Description
$a_e$	Radial depth of cut
AECM	Active energy consumption of the machine tool
AMGA	Archive based micro-genetic algorithm
AMOPSO	Adaptive multi-objective particle swarm optimization
ANN	Artificial neural network
$a_p$	Axial depth of cut
APCM	Active power consumption of the machine tool
ATR	Activity-Therblig relationship
C/O	Change over time
C/T	Cycle time
$C_{coolant}$	Coolant cost
$c_{coolant}$	Coolant price per liter
CE	Carbon emissions
CEC	Comprehensive energy consumption
$CE_{chip}$	Carbon emissions caused by the chips treatment
$CE_{coolant}$	Carbon emission caused by coolant
$CE_{elec}$	Carbon emission caused by electricity
$CEF_{chip}$	Carbon emission factor for chip processing
$CEF_{coolant}$	Carbon emission factor of coolant production
$CEF_{coolant-dis}$	Carbon emission factors of coolant disposal
$CEF_{elec}$	Carbon emission factor due to electricity production
$CEF_{material}$	Carbon emission factor of raw material production
$CEF_{tool}$	Carbon emission factor of the cutting tool
$C_{elec}$	Electricity cost
$CE_{material}$	Carbon emission caused by raw material production
$CE_{tool}$	Carbon emission caused by cutting tool
CEU	Comprehensive energy utilization
$C_L$	Labor cost
$C_{MT}$	Machine tool depreciation cost
CNC	Computer numeric control
Com-MGGP	Complexity based multi-gene genetic programming
$C_p$	Production cost
CSEC	Cutting specific energy consumption



<b>Abbreviation/Symbol</b>	<b>Description</b>
CSM	Current state map
$C_{tool}$	Cutting tool cost
$EC_{process}$	Energy consumption during machining process
$E_i$	Energy consumed by activity $i$
$E_j$	Energy consumed by Therblig $j$
$f$	Feed rate
FRP	fiber reinforced plastic
FSM	Future state map
$f_z$	Feed rate per tooth
GA	Genetic algorithm
HBMO	honey-bee mating optimization
HMM	Hidden markov model
$k$	Specific cutting energy of material
MEC	Machine energy consumption
MOBSA	Multi objective backtracking search algorithm
MOO	Multi objective optimization
MOPSO	Multi objective particle swarm optimization
MQL	Minimum quantity lubrication
MQL	Minimum quantity lubrication
MRR	Material removal rate
NC	Numeric control
NLP	Nonlinear programming
NNVAA	Necessary non-value-added activity
NSGA	Non-dominated sorting genetic algorithm
NVAA	Non-value-added activity
NVAT	Non-value-added Therbligs
OEC	Operator energy consumption
$P(t)$	Power drawn by machine tool at time $t$
$P_{air-cut}$	Air cutting power
PF	Power factor
$P_{ij}$	Power of $j^{th}$ Therblig in $i^{th}$ activity
PSO	Particle swarm optimization
PT	Processing time
$R_a$	Surface roughness
RPM	Rotation per minute

<b>Abbreviation/Symbol</b>	<b>Description</b>
RSM	Response surface methodology
S/N	Signal to noise ratio
SA	Simulated annealing
SCE	Specific cutting energy
SEC	Specific energy consumption
$s_{ij}$	Execution state of $j^{\text{th}}$ Therblig in $i^{\text{th}}$ activity
SOO	Single objective optimization
SQP	Sequential quadratic programming
STEP-NC	Standard for exchange of product model data-numerical control
$t_c$	Cutting time
$T_c$	Cutting temperature
$T_{\text{coolant}}$	Coolant replacement time
TEC	Total energy consumption
$t_i$	Duration of $i^{\text{th}}$ activity
TP	Therblig power
TT	Therblig time
$T_{\text{tool}}$	Cutting tool life
TVSM	Therblig-based value stream map
U	Energy utilization ratio
UM	Machine specific energy
$U_{\text{nc}}$	Net specific cutting energy
UNVAA	Unnecessary non-value-added activities
V	Cutting speed
VAA	Value-added activity
$V_{ad}$	Volume of additional cutting fluid used before replacement
VAT	Value-added Therbligs
$v_c$	Cutting speed
$V_{\text{coolant}}$	Total volume of coolant used before replacement
$V_{in}$	Volume of cutting fluid used initially
VMC	Vertical milling center
VSM	Value stream map
$W_{\text{chip}}$	Weight of chips produced
$W_{\text{tool}}$	Weight of cutting tool
$\alpha$	Concentration of the coolant

<b>Abbreviation/Symbol</b>	<b>Description</b>
$\eta_A$	Energy efficiency at the activity level
$\eta_T$	Energy efficiency at Therblig level
$\eta_{time}$	Time efficiency
$E_{sb}$	Total standby energy
$E_{st}$	Total starting energy
$E_u$	Total idling energy
$E_c$	Total cutting energy
$E_a$	Additional load loss
$\rho$	Density of workpiece material