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Tool path planning of hole-making operations in ejector plate of injection mould using modified shuffled frog leaping algorithm

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Abstract

Optimization of hole-making operations in manufacturing industry plays a vital role. Tool travel and tool switch planning are the two major issues in hole-making operations. Many industrial applications such as moulds, dies, engine block, automotive parts etc. requires machining of large number of holes. Large number of machining operations like drilling, enlargement or tapping/reaming are required to achieve the final size of individual hole, which gives rise to number of possible sequences to complete hole-making operations on the part depending upon the location of hole and tool sequence to be followed. It is necessary to find the optimal sequence of operations which minimizes the total processing cost of hole-making operations. In this work, therefore an attempt is made to reduce the total processing cost of hole-making operations by applying relatively new optimization algorithms known as shuffled frog leaping algorithm and proposed modified shuffled frog leaping algorithm for the determination of optimal sequence of hole-making operations. An industrial application example of ejector plate of injection mould is considered in this work to demonstrate the proposed approach. The obtained results by the shuffled frog leaping algorithm and proposed modified shuffled frog leaping algorithm are compared with each other. It is seen from the obtained results that the results of proposed modified shuffled frog leaping algorithm are superior to those obtained using shuffled frog leaping algorithm.

Keywords: Hole-making operations; Shuffled frog leaping algorithm; Modified shuffled frog leaping algorithm; Injection mould; Ejector plate

1. Introduction

Mould carries large number of holes of various sizes. In hole-making operations of mould, to achieve the final size of each hole may require different machining operations like drilling with pilot tool, enlargement or tapping/reaming depending upon requirement of diameter, surface finish and depth of cut. Machining of hole or holes may require tool or combination of tools to achieve the final size diameter of hole. E.g. for hole H_3 shown in Fig. 1, may require one of {T_1, T_2, T_3}, {T_1, T_3}, {T_2, T_3}, and {T_3} tools to obtain the final size. Various combinations of tools for individual hole to achieve the desired size of hole has impact on optimum cutting speeds, tool switch time and tool travel time [19].

In machining processes, it takes more machining time for tool switching and table movement from one position to another. To reduce the tool travel, the spindle is not moved till desired hole is completely machined by various tools which increases the tool switch time and cost. On the other side to reduce tool switch time, the same tool may be used for all drilling operations of same size which in turn increases the tool travel time and cost. Typically 70% of total time in manufacturing processes is spent on tool and part movements [27]. Luong and Spedding [25] presented the process planning in hole-making operations by developing a generic knowledge based methodology. Kolahan and Liang [19] report a tabu-search (TS) technique to reduce the total machining cost of hole-making operations of application example of plastic injection mould. Three components of total machining cost

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Nomenclature

X_{i+1}	New position of frog
X_i	Previous position of frog
r	Random number values between 0 to 1
X_b	Position of best frog among the memeplexes
X_w	Position of worst frog among the memeplexes
X_g	Position of global best frog in search space which best among all frogs.
w	Inertia weight
C_1	Search acceleration factor with positive values
C_2	Search acceleration factor with positive values
D	The total holes to be machined in the part
(x_d, y_d)	are the co-ordinates of point d
(x_e, y_e)	are the co-ordinates of point e
l_{de}	Non-productive tool travel time required for moving tool from the point d to the
point e	in rectilinear direction
d,	Tool type index in ascending order according to the tool diameters, $d=1,\ldots,D$
$e, f,$	Hole index, $e=1,\ldots,E$ $f=1,\ldots,E$
de,I	ndex for the last tool to be used on hole e
$C_{de,}$	Combined tool and machining costs when tool type d is used on hole e.
a	Cost per unit tool switch time
b	Cost per unit non-productive traveling time
m_{dT}	he total operations required for hole d., $d=1,2,\ldots,D$
M	$m_1+m_2+\ldots+\ m_D$, the total of operations in the part
T_{deT}	The tool required for operation e of hole d.
$a_{dd'}$	The tool travel time for traveling from hole d to hole d'
$S_{de,\ d'e'}$	The time required for switching the tool $T_{d'e'}$ when tool T_{de} is in spindle
X_{def}	1 if operation e of hole d is machined in position f of operation order, otherwise 0, where
d	$1,2,\ldots,D$, $e=1,2,\ldots,\ m_i$, $f=1,2,\ldots,\ M$
$\delta(T_{de},T_{d'e'})$	1 if $T_{de} \neq T_{d'e'}$, otherwise 0

namely tooling and machining cost, non-productive tool travel cost and tool switching cost were considered for the optimization of hole-making operations. Alam et al. [1] presented the case study of injection moulds with the aim of achieving minimum total processing time of machining using genetic algorithm (GA) and compared GA results with simulated annealing (SA). Qudeiri and Hidehiko [34] used genetic algorithm to obtain concise cutting tool path for machine operations. Liyun [22] presented the process planning optimization by using an genetic simulated annealing algorithm.

Guo et al. [10] modeled a complicated operation sequencing process and applied modified particle swarm optimization (PSO) algorithm on case study of three prismatic parts and compared the results of PSO with GA. Guo et al. [11] presented a case study of five-axis prismatic parts for sequencing the operations using modified particle swarm optimization approach.

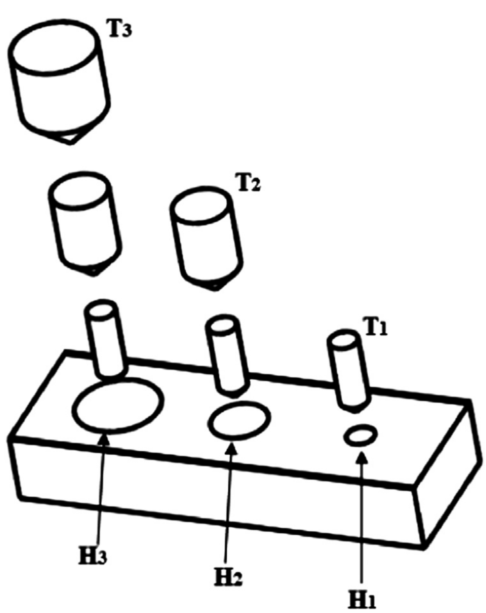

Fig. 1. Diagrammatic depiction of part which requires various tools to machine a hole to its final size [19].

Ghaiebi and Solimanpur [9] presented a case study by application of the ant colony optimization (ACO) algorithm for achieving optimal path of machining holes in a typical industrial part. Six bench mark problems were attempted in order to validate the performance of their ACO algorithm and compared ACO results with dynamic programming (DP). Oscar et al. [32] presented a methodology to generate optimal sequences of G commands to minimize the manufacturing time of computer numerical control machine (CNC) using ACO. Liu et al. [21] used ACO algorithm for process planning optimization of hole-making operations of a case study with objective to minimize non-productive tool time and tool switching time. Kiani et al. [18] used ant colony algorithm to achieve the optimal sequence of operations that gives concise cutting trajectory in computer numerical control machine. Narooei et al. [28] used ACO algorithm for optimizing the tool path i.e. to minimize non-productive tool travel of case study involving multiple holes. Simulation of machining operation is considered similar to traveling salesmen problem (TSP). Jiang et al. [16] compared the performance of ant colony optimization, genetic algorithm and the common sequence method for replugging tour planning of seedling transplanter. Results obtained using ACO and GA were more suitable than common sequence method.

Hsieh et al. [12] investigated the optimal sequence of hole-making operations by minimizing the non-productive tool travel time and tool switch time, in which various tools were required to obtain the desired size of hole on part using immune based evolutionary approach (IA) and compared its