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Multi-Quality Deduction Optimization for CNC Turning Using Triz and Game Theory

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Abstract: In this study, machining speed, feed rate, cutting depth and tool nose runoff are selected as control factors for the quality characteristics of surface roughness and tool wear in computer numerical control (CNC) turning. Based on surface roughness and tool wear, TRIZ (Theory of Inventive Problem Solving) method is additionally used to analyze 39 engineering parameters and to define the improvement and worsening factor of individual quality. Moreover, through 40 inventive principles corresponding to contradiction matrix and the use of Single-Characteristic rule, innovation strategy for single-objective and their orders are obtained and verified on an ECOCA PC-3807 CNC lathe. Furthermore, FAHP (Fuzzy Analytic Hierarchy Process) is used to analyze the deteriorated weight of each innovation strategy by the quality of the other side to formulate the payoff matrix for conducting negotiating game. Through the game system developed by Visual Basic, the dominant judgment and mixed solution-finding, multi-objective optimization scheme is thus obtained and verified experimentally. The result shows that multi-objective optimization scheme indeed enhance 50.41% on surface roughness and 50.04% on tool wear than those from the benchmark parameters.

Key words: TRIZ, game theory, decision support system, FAHP

INTRODUCTION

Computer Numerical Control (CNC) industry has higher and higher requirement on the manufacturing quality. It is necessary to select appropriate cutting parameters under minimum cutting cost to obtain optimum cutting conditions and apply to the CNC lathe (Yeo, 1995). The adductive network has also been used to construct the surface roughness and cutting force model of turning. It is found that the enhancement of initial surface speed can enhance the cutting efficiency (Lin *et al*., 1999). Furthermore, multi-goal competitive optimized cutting parameter analysis method is used to shorten the setting time of numerical control cutting operation and to enhance competitiveness in the industry (Liao, 2004). There are many scholars and experts apply this method to investigate the optimization of process parameters of single quality characteristic successfully (Dhavlikar *et al*., 2003; Kopac, 2002; Tarng *et al*., 2002; Syrocs, 2003). Through the use of CNC system and efficient experimental methods to find out optimized cutting parameters quickly is highly expected in engineering; however, it is still not good in handling problem with multi-qualities characteristic and linguistic variable. Therefore, how to improve the above mentioned problems and to propose a simple and effective solution became very important.

TRIZ (Theory of Inventive Problem Solving) is a set of simple, efficient and innovative problem-solving method, which finds out an optimization through the parameters of numerical control cutting operation. Terninko (1997) had proposed that TRIZ method should be used together with other quality design methods such as: Quality Function Deployment, Taguchi quality design method, by doing so, the designer should be able to design better product in the concept design stage; León-Rovira and Aguayo (1998) had proposed the concept that the relationship among technical parameters in quality function deployment table can be solved through contradiction matrix table, by doing so, the contradiction parameters of engineering problem can thus be found out correctly.

Through the innovation strategy proposed by TRIZ, quality can be enhanced and the level of the innovation strategy of each quality can thus be distinguished; however, economists had proposed Game Theory (Wu, 2004), which not only can be used to solve the level of innovation strategy and the multiple-person competition issue, but also, is widely used in different fields; it not only has the preciseness of a mathematical model, but also can simplify the complicated interactions in the real world, hence, it is the only method that can be used for strategic behavior analysis in the study of a decision

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maker (Wu and Chen, 2003; David, 1992; Rasmuse *et al*., 2003). Then further through FAHP theory (Thomas, 1980; Wu, 1999) had used fuzzy analytic hierarchy process and fuzzy general judgment to aim at companies in the semiconductor related industry for analysis and empirical survey so as to construct a management ability evaluation weighting system, finally, 8 major evaluation indexes and 39 sub-evaluation indexes are developed. It can be used to analyze the deteriorated weight of each innovative quality project on other quality; then through deteriorated weight and TRIZ Single Characteristic Rule (Liu and Chen, 2001), game matrix can be constructed to perform Multi-objective optimization scheme of two-persons competition; then through dominant judgment and mixed solution-finding in game theory, the equilibrium solution of Multi-objective optimization scheme is found and finally, when quality contradiction occurs, a new game is then started so, as to reach the final equilibrium solution.

In order to improve quality, unique method has been developed to be used as new principle for the quality improvement and future quality development in the numerical control cutting field; it is hoped that through this study, the processing industry can have new solution strategy on the continuous improvement of quality; hence, in order to enhance the quality, an universal multi-qualities optimized decision making system is proposed, which is an important topic in the processing process aspect.

MATERIALS AND METHODS

In this study, the quality goal can be divided into two categories: surface roughness and tool wear. Surface roughness is dependent on the processing method adopted and other factors; the processed surface has smaller spacing between peak and valley in the microscopic scale and geometrical characteristic. Tool wear is the general result of physical reaction and chemical reaction generated by cutting heat and mechanical friction. The control factors of two qualities in the cutting process are selected as: surface speed, feed rate, cutting depth and tool nose runoff and they are used as level parameters (Nian *et al*., 1999). By taking into account all the cutting parameters and the required quality characteristic, the cutting performance of re-cutting process is then evaluated. That is, surface roughness and tool wear are highly related to cutting parameters such as: surface speed, feed rate, axial cutting depth and radial cutting depth, etc.

To solve multi-qualities issue and control factor, Altshuller (1998) and his research group had invented TRIZ theory; furthermore, in order to solve engineering contradiction, solution of Inventive Principles has been developed and he thought that the process of finding solution for contradiction is the chance for innovation and invention. TRIZ can be used to solve quality characteristic and control factor issues effectively and to propose innovation strategy.

Laarhoven and Pedryce (1983) further evolved the conventional analytical hierarchy method of Thomas (1980) and developed fuzzy analytic hierarchy process; they further substitute the triangular fuzzy number directly into paired comparison matrix to avoid the fuzzy questions generated in the process of handling principle evaluation and judgment (Lo, 2006); therefore, quality characteristic is like the-larger-the-better characteristic, smaller-the-better characteristic and fitness, it contains certain degrees of uncertainty and fuzzy nature. Therefore, TRIZ and FAHP are associated in this study to develop multiple quality characteristic that contains fuzzy design goal; through the use of fuzzy logic, the multi-qualities characteristic is converted into single quality characteristic and the weighting of the cutting parameter is then obtained.

Cutting performance evaluation: In order to understand the focus of quality characteristic, the quality characteristic performed by two researchers (Liao, 2004; Weng, 2007) on surface roughness and tool wear is going to be used first, then fuzzy semantics (Weng, 2007) and experimental data (Liao, 2004) will be further used to define TRIZ issues; in this study, surface roughness and tool wear will be studied first.

Surface roughness: For the study of surface roughness in the CNC turning field, there are many uncertain factors in the influential factors, from the prior study, the researcher has proposed an empirical formula (Petropoulos *et al*., 2006), which is $R_i(i = a, zD, t, p, q, 3z) = C_i V^{mi} f^{ni}$, wherein, $V(m\,min^{-1})$ is initial surface speed which will affect the cutter lifetime, that is, the larger V is, the shorter the lifetime; f(mm/rev) is the feed rate, C_i, mi, ni are parameters that can be used surface roughness of different principle; the equation has mentioned that initial surface speed and feed rate are factors that have deeper effect and the rest are constants; in this study, four control factors are going to be considered and these factors are going to be used for rule setup and for selecting optimized quality.

Tool wear: For the cutter lifetime proposed by Taylor and for high speed steel cutter, it means the time in the upper time of the low wear region and it is used to describe the HSS cutter characteristic; through re-arrangement and generalization, we can obtain the formula: $TV^{1/n} f^{1/m} d^{1/1} = C$ (Lin and Chi, 1987), wherein, T is the cutter performance, V is surface speed, f is feed rate, d is the cutter diameter; furthermore, the relationship between feed rate and surface speed should be well controlled, that is, is should not be too slow, too slow might sometimes lead to friction instead of cutting, too fast might lead to blade breaking or rough surface. In the formula, initial surface speed, feed rate and cutting depth are mentioned as influential factors; moreover, cutter lifetime is very sensitive to speed change, but is least sensitive to cutting depth change; hence, surface speed and feed rate are used for semantic judgment and the importance of two factors are investigated through experimental data; finally, cutting depth and tool runoff are proposed.

Deducing new strategy: First, four factors of the cutting parameters are used as the main axis. According to the definition, this study adopts surface speed, cutting depth, feed rate and tool runoff in the definition. The cutting performance of this study is evaluated as in the followings:

TRIZ definition
Surface roughness:

- When the speed is fast and the feed rate is slow, the surface roughness will be better (Surface speed)
- When the cutting depth is decreased, surface roughness will be improved (Cutting depth)
- When the feed rate is slow, surface will be smoother
- According to the 81 sets Taguchi method of the data in the thesis of Yi-Tse Weng, it is found that level 2 is the best, that is, in the manufacturing process, the most stable process is to use medium value to perform the cutting (Tool runoff)

Tool wear:

- Slower cutting will reduce tool wear (surface speed)
- Smaller cutting depth will have smaller tool wear (cutting depth)
- Slower feed rate will have smaller wear
- According to the 81 sets Taguchi method of the data in the thesis of Weng (2007), it is found that level 1 is the best, that is, in the manufacturing process, the most stable process is to use medium value to perform the cutting (Tool runoff)

Engineering parameters: TRIZ 39 engineering parameters are used to be corresponded to the definition requirements and the factors to be improved and the worsening factors showing that TRIZ really follow 39 engineering parameters are proposed; in the Table 1 of this study, the parameter to be improved is on the left side, the worsening factor is on the right side.

Contradiction matrix: In this study, TRIZ is used to define conditional formula. Arrangement is done through contradiction matrix and then 40 inventive principles are applied with the values in the Table inserted to form TRIZ contradiction matrix as in Table 1.

Single characteristic rule: The frequencies of emergence of all the innovative rules of this study are summarized as a Table 1, the higher the rank is, the higher the frequency of use of the innovative rule, that is, the innovative rule has higher chance to be successful in solving problems; it can be seen that even under the situation that system contradiction is still unknown, we can still use 40 inventive principles to solve the problem and find out an innovative rule corresponding to single engineering characteristic.

Through the above mentioned four steps, we can find TRIZ Single-objective innovation strategy and the medium value that is frequently used in the industry is used to perform verification experiment so that the innovation strategy proposed in this study can be very convincing.

Strategy verification: In this study, the experimental equipment adopted ECOCA PC-3807 CNC lathe as manufactured by ECOCA Industrial Co., Ltd. S45C medium carbon steel is adopted as experimental processing material, which is a processing material commonly adopted by the industry; the turning material spec is, the holding length is 100 mm S45C medium carbon steel. The cutter adopted is ready-to-use disposable cutter with handle of model No. TJNR2020K16 manufactured by Toshiba; the cutter used is of model No. NX2525 manufactured by Mitsubishi. MITSUTOYO SURFTEST SV400 surface analyzer is used in this study to analyze the surface roughness of cutting result, the measured surface roughness value is selected as Ra.

The correctness of parameter defined by TRIZ as in this study might be questioned by people, hence, Table 2 for how to confirm the correctness of the definition so, that the TRIZ innovation strategy and

Table 1: A simple table showing the correspondence between contradiction matrix and 40 inventive principles

	Worsening parameter			
Parameter to be improved	Weight of a moving object	Weight of a still object	…	Productivity
Weight of a mobile object	*		-	35.3 24.37
Weight of a still object		*		1.28 15.35
⋮			*	
Productivity	35.26 24.37	28.27 15.30		*

Table 2: CI and RI of each perspective

Perspective	CI	RI
Surface roughness	0.04819	0.05354
Tool wear	0.04671	0.05190

parameter as proposed in this study can be corresponded to the benchmark parameters (Surface speed- 200 m min^{-1}, Cutting depth- 1 mm, Feed rate- 0.06 mm rev^{-1}, Tool runoff- ±0.03 mm) that are commonly used in the industry.

Through TRIZ, the innovation strategy is verified and improved values are acquired for all the innovation strategy through verification; moreover, through FAHP, quality item weighting is performed for the investigation of multi-qualities characteristic deteriorated weight.

Quality weight: In this study, oth layer is used as CNC turning quality deteriorated weight and first layer is surface roughness and tool wear, second layer is surface speed, feed rate, cutting depth and tool runoff; FAHP is used to solve the index corresponding to the first layer so, that the indexes (surface speed, feed rate, cutting depth and tool runoff) of the two layers will be the same; for indexes that will affect each other, FAHP can be used to calculate the deteriorated weights of the indexes.

Set up hierarchy structure: In this study, KJ method is going to be used to set up hierarchy structure. According to a suggestion from Thomas (1980), factors within each hierarchy should not exceed seven, but if it does exceed, it could be divided further into other hierarchies. The 0th layer represents an evaluation of the CNC turning quality deteriorated weight (Fig. 1). In this study, the first layer is used to represent the major factor structures that will affect the final goal; they are respectively surface roughness and tool wear. The second layer is used to represent indexes that will affect the major factors, they are respectively, surface speed, feed rate, cutting depth and tool runoff.

Consistency Index (CI) and Random Index (RI): The respective CI value and RI value of two perspectives are shown in Table 2, they are respectively: CI value of surface roughness = 0.04819, CI value of tool wear = 0.04671 and the RI value of surface roughness = 0.05354, RI value of tool wear = 0.05190, that is, they are all smaller than 0.1, in other words, Transitivity Law in the mathematic is met. Saaty suggests that CI≤0.1 is tolerable error range and it can be seen that each perspective has reached consistency.

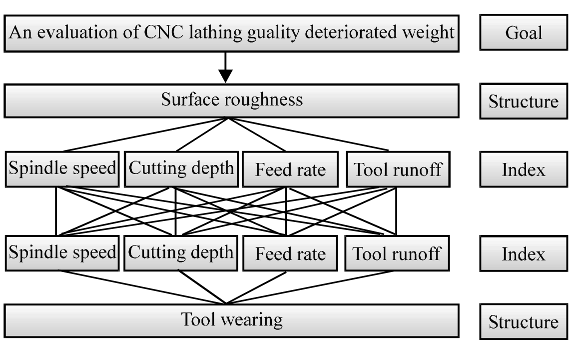

Fig. 1: Evaluation of the CNC turning quality deteriorated weight

Multi-qualities optimization competition: From the result of TRIZ, we can find the factor that needs to be improved for each goal; the result of TRIZ includes all the improved situations (for example, increase, no change or reduction) such as surface speed, cutting depth, feed rate and tool runoff. In real situation and under the consideration of time factor, what is the factor that needs to be improved in the first priority for each goal has thus become the key in process improvement. Therefore, in this study, through price negotiation Game Theory, we are able to find what are the factors that need to be improved first among all the factors to be improved so as to facilitate more efficiency operation of the process; in the following, we are going to describe the game participators briefly and Optimization System for Multiple-quality that is to be negotiated, respectively.

When individual quality is independent agent: Select two participators, they are the emergence frequencies of the innovation strategy summed up for respective qualities, to perform four major projects; meanwhile, the emergency frequencies will be used for the original scores of the project and will be introduced into the Game Theory; take A as tool wear, B as surface roughness, A1~A4 and B1~B4 as surface speed, feed rate, cutting depth and tool runoff (Table 3).

Set up the payoff matrix for a game: Set up the corresponding payoff value of payoff matrix (Table 4). In this study, the single characteristic quality is considered,

Table 3: Participator and project

Participator (Goal)	Project (Factors to be considered)
A surface roughness (the-smaller-the better)	(A-1) and (B-1) surface speed
B Tool wear (the-smaller-the better)	(A-2) and (B-2) cutting depth
	(A-3) and (B-3) feed rate
	(A-4) and (B-4) tool runoff

Table 4: Initial matrix

		Tool wear			
A	B	B-1	B-2	B-3	B-4
Surface roughness	A-1				
	A-2				
	A-3				
	A-4				

Table 5: Payoff matrix

A	B	Tool wear B-1	B-2	B-3	B-4
Surface roughness	A-1	(Pa1, Pb1)	(Pa2, Pb2)	(Pa3, Pb3)	(Pa4, Pb4)
	A-2	(Pa5, Pb5)	(Pa6, Pb6)	(Pa7, Pb7)	(Pa8,Pb8)
	A-3	(Pa9, Pb9)	(Pa10, Pb10)	(Pa11, Pb11)	(Pa12, Pb12)
	A-4	(Pa13, Pb13)	(Pa14, Pb14)	(Pa15, Pb15)	(Pa16, Pb16)

respectively, then under a correspondence of all the projects in the other side, we can perform optimization and worsening effect correction according to the original score of the projects considered, finally, we can get corrected score and use it as corresponding payoff value; through the FAHP deteriorated weight of this study, expert's opinion survey will be performed and the deteriorated weight to it from the projects in the other side is analyzed and acquired under single quality perspective; then through correction (Original score×deteriorated weight = Score after correction), the original score can be converted to corrected score and can be used as corresponding payoff value in the matrix.

Dominate strategy: The corrected scores of all the strategies in the payoff matrix are then filled in the corresponding columns to generate two persons multiple strategies game payoff matrix (Table 5). Then dominates strategy judgment will be performed on the matrix, certain strategy taken by certain side is usually better than another strategy and matrix simplification must be performed first (Table 6).

When target A is of maximum payoff value, does maximum payoff value need to be taken by target B for reply? At this moment, when both sides take maximum payoff value for reply, then the strategy combination is of equilibrium solution; if the situation is not so, this action will be continued until equilibrium solution is obtained.

Convergence situation: The possibly generated four convergence situations are as follows:

- Single equilibrium solution (converged to certain intersection) is 1×1 matrix; in this situation, the optimum equilibrium solution will be sent out and defined as the negotiated result of this game
- Approximate equilibrium solution (the condition when the strategy items of one side converges to single strategy) is 1×N or N×1 matrix; under this situation, only the undecided side needs to be considered and reply strategy item of higher payoff value should be selected; to the game participator that has strategy decided, the adoption of that strategy will lead to the acquisition of larger payoff for sure

Table 6: Simplified payoff matrix

A	B	Tool wear B-1	B-2
Surface roughness	A-1	(Pa1, Pb1)	(Pa2, Pb2)
	A-2	(Pa3, Pb3)	(Pa4, Pb4)

- Double equilibrium solution (the solution is found through combination strategy way) is 2×2 matrix: this situation is fully symmetrical equilibrium status and combination strategy can be used to find out if there is feasible strategy combination
- No equilibrium solution (solution is found through combination strategy way) is of 2×2 matrix: this situation is to form certain cycle and through combination strategy, what kind of equilibrium strategy combination can be used to acquire maximum expected payoff is found out
- Multiple persons and multiple strategies optimization strategy

In this study, two quality indexes (agents) of precise numerical control turning are considered to conduct two games and the solutions and probability values generated from all the games are used to perform strategic probability estimation; then the strategy item that has the highest total probability value is selected and used as the optimal strategy of that quality goal; in the mean time, the optimal strategy and adoption probability of each quality goal is listed to obtain multiple persons (multi-qualities) Multi-objective optimization scheme.

Perform strategic correction on agent of contradiction side: In this study, the contradiction situations generated among the optimal strategies of all the quality goals will be considered; then strategic correction is performed on the agent of contradiction side through the conservation of strategic item that has the highest probability value; the detailed correction steps are as in the followings:

Select replacement strategic project: Perform another judgment on the suggested strategy of ranking two of the agent of the contradiction side; if this strategy is found to cause no contradiction on all other agents, then this suggested strategy is used as the optimization project of final strategy.

Delete the strategy and re-start the game: If after the above processing, the contradiction still exists, then the strategy that causes contradiction is deleted directly; then other strategy items are used again to re-start a new game so as to find out, under the consideration of entire agent, the best optimization project of multiple persons and multiple strategies.

RESULTS AND DISCUSSION

TRIZ strategy and verification: In this study, TRIZ is used to propose Single-objective innovation strategy and the cutting parameters commonly used in the industry are used as reference, then verification is performed through experimental tools and cutting parameters; the following is the innovation strategy and verification result:

Innovation strategy: Characteristics that need to be improved for surface roughness and tool wear are surface speed, feed rate, cutting depth and tool runoff. Thirty nine engineering parameters correspond to two goals; for surface roughness, the characteristic parameters to be improved are 9, 12, 19 and 29 and the possibly worsening characteristics are 10, 13, 9, 25, 39, 11, 22 and 31; for tool wear, the characteristic parameters to be improved are 9, 12, 11, 19 and 29 and the possibly worsened characteristics are 25, 39, 22, 10, 11, 9 and 33; from the contradiction matrix table, we can find 40 inventive principles, for surface roughness, it is 19, 14, 15, 35, 4 and No. 17, for tool wear, it is 18, 14, 34 and No. 35.

In this study, the innovation strategy taken through the use of 40 inventive principles are respectively as follows: for surface roughness, they are surface speed increase, feed rate increase, cutting depth decrease and upward movement of tool runoff; for tool wear, they are surface speed increase, feed rate increase, cutting depth increase and centering of tool runoff; furthermore, verification is done in Single-objective innovation strategy through the parameters that are frequently used in the industry so, as to enhance the correctness of the study.

Verification: Data comparison is performed in this study. The medium value of surface roughness (Table 7) is 0.9233 (μm) and the medium value of tool wear (Table 8) is 4.38E-0.7 mm^{-2}.

In this study, data found from TRIZ are used to find further solution. The experimental data of surface roughness (Table 9) is 0.6033 (μm) and the experimental data of tool wear (Table 10) is 3.55E-0.7 mm^{-2}; they are indeed better than the medium value experimental data, which proves that the innovation strategy proposed by TRIZ is feasible.

Through medium value comparison, it can be seen that surface roughness and tool wear has broken through the data in the turning industry. TRIZ has proposed an optimization project that can improve surface roughness and tool wear; this project is very amazing because no experiment is needed to obtain optimized surface roughness and tool wear.

Optimization system for multiple-quality: In this study, TRIZ solution-finding and expert questionnaire are used together and the design of hierarchy structure is for the pursuit of Single-objective innovation strategy. Twelve survey questionnaires are issued in this study and the actual returned copies are 12, with a return rate of 100%; the effective No. is 10 professional survey questionnaires; moreover, the survey target are four questionnaires for the academy and four questionnaire for the industry; for the four questionnaires in the industry, the CI values and RI values must be smaller than 0.1. Then multi-qualities weighting is acquired and TRIZ is used to propose Single-objective innovation strategy and quality weighting to set up payoff matrix, then through the use of mixed solution way, Multi-objective optimization scheme and probability are acquired.

Table 7: The medium value experimental data of surface roughness

Surface speed (m min^{-1})	Cutting depth (mm)	Feed rate (mm rev^{-1})	Tool nose runoff (mm)	Surface roughness (μm)
200	1	0.06	±0.03	0.9233

Table 8: The medium value experimental data of tool wear

Surface speed (m min^{-1})	Cutting depth (mm)	Feed rate (mm rev^{-1})	Tool nose runoff (mm)	Tool wear (mm^{-2})
200	1	0.06	±0.03	4.38E-0.7

Table 9: The experimental data of surface roughness

Surface speed (m min^{-1})	Cutting depth (mm)	Feed rate (mm rev^{-1})	Tool nose runoff (mm)	Surface roughness (μm)
250	0.5	0.1	0.1	0.6033

Table 10: The experimental data of tool wear

Surface speed (m min^{-1})	Cutting depth (mm)	Feed rate (mm rev^{-1})	Tool nose runoff (mm)	Tool wear (mm^{-2})
250	1.5	0.1	±0.03	3.55E-0.7

Table 11: Deteriorated weight of surface roughness and tool wear

The deteriorated weight of surface roughness		The deteriorated weight of tool wear	
Tool wear-initial surface speed	Last weight	Surface roughness-initial surface speed	Last weight
Surface roughness-initial surface speed	0.076169046	Tool wear-initial surface speed	0.055636768
Surface roughness-cutting depth	0.092901312	Tool wear-cutting depth	0.047448932
Surface roughness-feed rate	0.090014776	Tool wear-feed rate	0.058680895
surface roughness-tool runoff	0.051341759	Tool wear-tool runoff	0.043288154
Tool wear-cutting depth		**Surface roughness-cutting depth**	
Surface roughness-initial surface speed	0.055670589	Tool wear-initial surface speed	0.045067095
Surface roughness-cutting depth	0.052326941	Tool wear-cutting depth	0.057589648
Surface roughness-feed rate	0.071897718	Tool wear-feed rate	0.084827519
Surface roughness-tool runoff	0.020829584	Tool wear-tool runoff	0.020417608
Tool wear-feed rate		**Surface roughness-feed rate**	
Surface roughness-initial surface speed	0.095200376	Tool wear-initial surface speed	0.047334974
Surface roughness-cutting depth	0.085074329	Tool wear-cutting depth	0.104257356
Surface roughness-feed rate	0.121381959	Tool wear-feed rate	0.11265555
Surface roughness-tool runoff	0.059820137	Tool wear-tool runoff	0.089289957
Tool wear-tool runoff		**Surface roughness-tool runoff**	
Surface roughness-initial surface speed	0.032347682	Tool wear-initial surface speed	0.034490177
Surface roughness-cutting depth	0.020014162	Tool wear-cutting depth	0.063463873
Surface roughness-feed rate	0.032095695	Tool wear-feed rate	0.066339449
Surface roughness-tool runoff	0.042913935	Tool wear-tool runoff	0.069212044

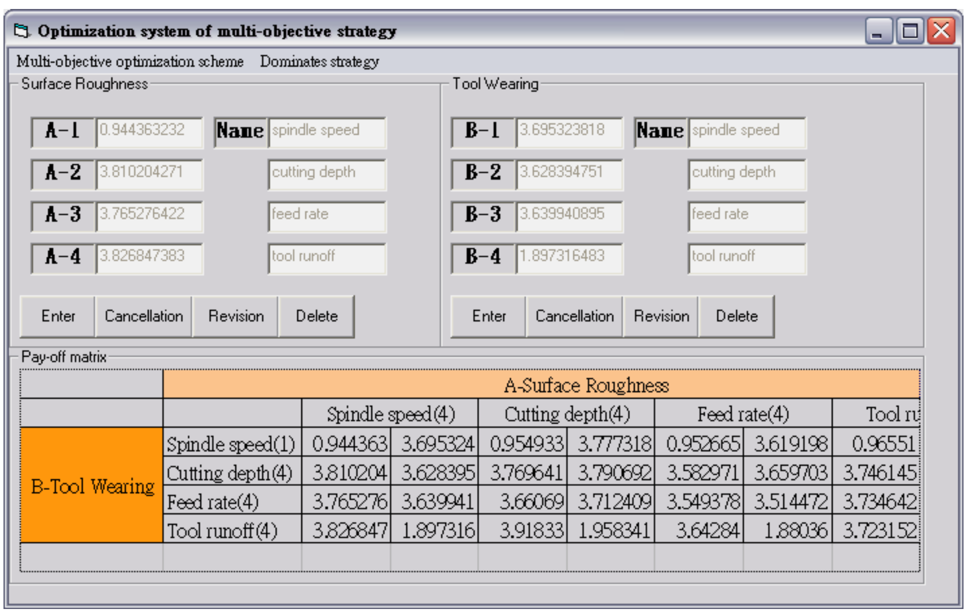

Fig. 2: Optimization system of multi-objective strategy

Deteriorated weight: Geometrical mean is used to arrange the weightings given by 10 effective expert questionnaires; it can be seen from Table 11 that surface roughness and tool wear has the highest weighting, which means that they have larger influence.

Payoff matrix: In this study, solution is found through combination strategy and the calculated result of surface roughness and tool wear is obtained (Table 12); it is hoped that the newest strategy is obtained and Multi-objective optimization scheme is listed.

Table 12: Multi-objective optimization scheme

Perspective (agent)	Optimization strategy	Probability of adoption (%)
Surface roughness	Cutting depth	50.41
Tool wear	Feed rate	50.04

System development: In this study, VB is used to develop optimization system of multiple persons and multi-qualities strategy (Fig. 2); writing job is performed through experimental planning steps and interface that dominates the strategy and inter-contradiction function of multiple persons and multi-qualities strategy is then developed.

CONCLUSIONS

In this study, Computerized Numerical Control (CNC) turning is used to perform the quality optimization strategy of surface roughness and tool wear; because numerical conditions can not be clearly selected for the optimization of turning quality, hence, in this study, TRIZ is used to propose Single-objective innovation strategy so as to perform verification; through the verification, surface roughness is enhanced by 65%, tool wear is enhanced by 85% and it is found that the strategy proposed in this study can indeed enhance cutting quality, there is no need of actual cutting and the data is optimized at the medium value; furthermore, Game Theory is used to find out Single-objective innovation strategy proposed by TRIZ and mutual competition is allowed to happen so as to obtain Multi-objective optimization scheme; the result shows that the best strategy for surface roughness is cutting depth strategy and the best strategy for tool wear is feed rate strategy; Optimization System for Multiple-quality can add new idea to the processing industry, it can also enhance industry profit and enhance the production quality; in the future, other multiple qualifies goals can be added, or Quality Function Deployment (QFD) can be accompanied so that numerical control turning goal (quality) can be optimized.

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REFERENCES

Altshuller, G., 1998. To Find An Idea. http://www.altshuller.ru/world/eng, USA.

David, M.K., 1992. Game Theory and Economic Modeling. 1st Edn., Clarendon Press, Oxford, USA.

Dhavlikar, M.N., M.S. kulkarni and V. Mariappan, 2003. Combined taguchi and dual response method for optimization of a centerless grinding operation. J. Mater. Proc. Technol., 132: 90-94.

Kopac, J., 2002. Optimal machining parameters for achieving the desired surface roughness in fine turning of cold pre-formed steel workpiece. J. Mach. Tools Manuf., 42: 707-716.

Laarhoven, P.J.M. and W. Pedryce, 1983. A fuzzy extension of Saaty's priority theory. J. Mater. Process Fuzzy Sets Syst., 11: 229-241.

León-Rovira N. and H. Aguayo, 1998. A new model of the conceptual design process using QFD/FA/TRIZ. The TRIZ. J. Part Real Innovation Network.

Liao, C.K., 2004. A Study on the Competitive Type Multiple Goals Optimized Cutting Parameters. 1st Edn., Graduate Institute of Mechanical Engineering, Tatung University ROC.

Lin, W.H. and S.S. Chi, 1987. Cutting Theory. 1st Edn., Chuan Hwa Book Co. Ltd., ROC.

Lin, W.S., B.Y. Lee and C.L. Wu, 1999. Modeling the surface roughness and cutting force for turning. J. Mater. Process. Technol., 108: 286-293.

Liu, C.C. and J.L. Chen, 2001. Development of product green innovation design method. Proceedings of the 2nd Environmentally Conscious Design and Inverse Manufacturing, (EcoDesign'01), pp: 168 2001 IEEE Computer Society, pp: 168-168.

Lo, Y.F., 2006. The development of innovation-assisted system for a product. Ph.D Thesis. Graduate Institute of Industrial Engineering and Management. National Chiao Tung University, ROC.

Nian, C.Y., W.H. Yang and Y.S. Tarng, 1999. Optimization of turning operations with multiple performance characteristics. J. Mater. Processing Technol., 95: 90-96.

Petropoulos, G., F. Mata and J. Paulo Davim, 2006. Statistical study of surface roughness in turning of peek composites. J. Mater. Des., 29: 218-223.

Rasmuse, E., C.Y. Yang, C.Y. Chang and L.C. Wu, 2003. Game Theory and Information Economy. 1st Edn., Wu-Nan Book Inc, ROC.

Syrocs, G.P., 2003. Die casting process optimization using taguchi methods. J. Mater. Processing Technol., 135: 68-74.

Tarng, Y.S., S.C. Juang and C.H. Chang, 2002. The use of grey-based taguchi methods to determine submerged arc welding process parameters in hardfacing. J. Mater. Process. Technol., 128: 1-6.

Terninko, J., 1997. The QFD, TRIZ and taguchi connection: Customer- driven robust innovation. The TRIZ Journal Part of the Real Innovation Network.

Thomas, L.S., 1980. The Analytic Hierarchy Process. 1st Edn., McGrae-Hill, New York.

Weng, Y.T., 2007. A study of the optimization of multiple goals numerical controlled turning through the use of fuzzy semantics method. M.Sc. Thesis. Tatung University ROC.

Wu, C.H., 2004. Value Evaluation and Strategy of Individual Acquisition of Domestic Airline Companies-the Application of Real option and Game Theory. 1st Edn., Department of Management, National University ROC.

Wu, H.M. and H. Chen, 2003. To Game Player. 1st Edn., Published by Times Publishing Co, ROC.

Wu, Y.H., 1999. A Study of the Application of Fuzzy Analytic Hierarchy Process and Management Ability Evaluation Model. 1st Edn., Graduate Institute of Human Resource Management, National Sun Yat-sen University ROC.

Yeo, S.H., 1995. A multi-pass optimization strategy for CNC lathe operations. J. Prod. Econ., 40: 209-218.