Critical Analysis of the Selection of Non-Conventional Machining Processes

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Abstract - Non-Convectional Machining (NCM) processes are used widely to produce accurate and intricate material shape such as titanium, stainless steels and resistant alloy that are of high strength, fiber-based composite, refractories and ceramics. The production of more complex shapes of materials using convectional machining processes is considered to be challenging. This research paper focusses on the section of the most effective NCM process. The 'choice' of the most considerable NCM process for a particular application could be seen as a multi-technique for making proper choices for diverse or conflicting approaches. To aid the process of choosing, various NCM techniques have been proposed in this research. This contribution focuses on the usage of unexplored NCM and Multi-Feature Decision-Making (MFDM) 'choice' issues.

Keywords - Non-convectional Machining (NCM), Convectional Machining (CM), Multi-Feature Decision-Making (MFDM).

I. INTRODUCTION

Modern machining techniques are also known as Non-convectional Machining (NCM) methods. These techniques create segments of procedures that eliminate excess materials by different methods involving electrical chemical energy, mechanical thermal energy or a collaboration of these energies. With the methods, there is no cutting of metals with using metallic tools using sharp cutting edges. The key purpose of the popularity and development of modernized machining approaches are:

- Machining both metals and non-metals that have just been developed with critical features such as high toughness, high harness and high strength. The processing of materials based on the above mentioned features are difficult to be machined properly by Convectional Machining (CM) approaches.
- Producing more complex geometrics that cannot be generated by CM approaches. NCM provide the best surface finish that might also encourage the application of these methods.

For the use of energy principles, the usage of mechanical energy is based on the removal of materials from workpieces. With this process, the tools of cutting with sharp edges are not utilized but the materials are eliminated using abrasive actions of high-speed streams of hard, smaller abrasive particles. Particles vibrate with high speed and ultra-high frequencies to eliminate materials. The usage of electrical energy is based on electro-chemical energy or electro-head energies to erode materials or to vaporized and melt. Electro-chemical machining, electro-discharge and electro-plating are some of the principles. The usage of thermal energy is based on heat that is generated using electrical energies. Generated thermal energies are based on minimal portions of workpieces. Heat is used in evaporation and melting of metals e.g. electrical discharge machining. Lastly, the usage of chemical energy is based on the erosion of materials from workpieces. The choice of chemical is based on the workpiece materials. Some of this form of machining is electro-chemical machining. This same principles is applicable in reverse manner during electro-chemical plating.

Based on the Multi Approach Decision Making (MADM) approach (systematic order procedure and method for order preferences by the concept of similarity to ideal solutions), V. Sharma and S. Kumar in [1] have simplified NCM procedure 'choice' process for manufacturing personnel. Some feasible NCM procedure satisfying the requirement of users was initially generated and those procedures were ranked with respect to their suitability to meet the required machining standards and operations. P. Chaudhury and S. Samantaray in [2] developed professional systems for choosing the best NCM procedure under constrained machining and material conditions. It would depend on the priority figures of various criteria and sub-criteria for particular NCM procedure 'choice' issue, and NCM procedure with higher acceptability index was finally recognized.

In the past, there have been fundamental developments in use and application of NCM processes, mostly in the machining of harder materials such as stainless steel and titanium. These materials are widely used in modern industry because of their developed mechanical features. These materials have different application in product manufacturing. These materials cannot easily be machined economically using CM processes. In competitive business ecosystems, consumers project higher accurate products with lower costs, hence process and cost optimization using CM approaches is not suitable. This stimulates the usage of NCM approaches.

Unique features of NCM processes include no direct connection between a workpiece and a tool. Moreover, in this process, huge energy amounts can be constrained in every unit area. Moreover, the process of 'choice' becomes more significant since all machining processes cannot be completed using a single approach. In that case, we need to select an efficient approach for various machining procedures. In addition, as we comprehend the efficiency and significance of NCM over CM, it provides us the merits over it and NCM processes stimulates development that has to be accomplished each day. NCM process also provides use the way for different innovations and it makes us design complex geometrical shapes. These conditions lead to significant market competition. As there are challenges in the choice of NCM process, the choice is made easier based on the application of the classification code with sixteen digits. In this case, the optimization process selection can be accomplished as all the approaches are encrypted in databases of systems. To conduct these 'choice' procedures, professional human resources are required and structured techniques have to be incorporated.

In this research paper, Section III focusses on a literature survey of various selection methods and processes that the 'choice' of processes is accomplished. The paper is systematically organized as follows: Section II presents the background analysis of this research. Section III evaluates the relevant literature sources. Section IV presents a critical analysis of NCM processes. Section V finalizes the paper.

II. BACKGROUND ANALYSIS

This paper starts with the introduction of modern machining techniques i.e. Non-convectional Machining (NCM) methods. These techniques form segments of procedures that eliminate excess materials by different methods involving electrical chemical energy, mechanical thermal energy or a collaboration of these energies. With the methods, there is no cutting of metals with using metallic tools using sharp cutting edges. This paper, in the literature review section, evaluates the essential literatures and scholastic texts about NCM process, which also focusses on the various classes of NCM.

Section IV focusses on a critical analysis of NCM, where discussion of Various NCM Operations, Process Features and Choosing Machining Processes has been done. From the research, it is seen that complex designed products can be produced based on work piece materials based on the application of the best NCM procedures. These procedures include: Deep cutting, Shallow cutting, Drilling operations, Precision cavities, Standard cavities, Double contouring, Surface revolution, and Finishing.

For the NCM process features, some of the process features have a direct implication on effectiveness and productivity of NCM processes. These features include: Corner radius (units: mm), Overall cost, Current features in (A), Volumetric rate of removal of materials (mm3/min), Energy rating in (W), Safety scale in (R), Surface damages in (mm), Surface finish, Taper, Tolerance (all in mm) and noxiousness.

In Choosing Machining Processes, this paper starts with the evaluations of Operation Competitiveness Rating Analysis (OCRA) and Quality Functional Development Processes (QFDP). The process features that are obliged for attaining the essential product features are Application of materials, Shape applications, Capital investments, Fixtures and tooling, Energy requirement, Efficiency, Process capability and Tool consumption. This paper ends with a discussion of QFDP Development, which focuses on the NCM Process 'Choice' Framework and the Techniques for Order-Inclination connecting Similarity to Ideal Solutions and Analytical Hierarchy approach.

III. LITERATURE REVIEW

N. Kuruvila and H. Ravindra in [3] evaluated Non-convectional Machining (NCM) processes and classified them with respect on the conditions of energy incorporated in machining. These classifications include mechanical machining procedure, which is a process where mechanical energy is applied in the erosion of unwanted materials based on the application high-speed water jet and abrasives. Different machining procedures, which use mechanical energies incorporate ultra-sonic machining, abrasive flow machining, abrasive water jet machining, magnetic abrasive finish, and water jet machining.

E. Wenger, M. Epstein and A. Kribus in [4] evaluated electric and chemical energy, which is a process classification where materials are eroded using techniques of non-displacement or using chemical dissolution with chemical etchants or reagents (alkaline, acid solutions). This process necessitates higher current as major source of energy and the electrolyte considered as the foundational medium of the procedure to follow. To enhance the capability of machines and enhance efficiency of processes, various types of energy are combined to form hybrid NCM process. Machining procedures that incorporate chemical energy incorporate electro-chemical process, electrical and chemical grinding, chemical homage, electrical deburring and electro-chemical machining.

M. Darwish, P. Neumann, J. Mizsei and L. Pohl in [5] evaluated electro-thermal and thermal energies as another classification of NCM. Thermal energy is used to vaporize and melt smaller areas of workpieces by focusing heat energies e.g. heat developed because of high voltages, ionized materials and amplified light. Machining procedures, which use thermal energy incorporate: electrical discharge machining, electro-beam machining, laser beam machining, plasma arc machining, wire-electrical discharge machining and ion-beam machining among others.

T. Doke, S. Hayakawa, F. Itoigawa and T. Nakamura in [6] argued that electrical discharge machining and wire-electrical discharge machining necessitate medium to be used for energy transfer. Other processes evaluated by the researcher include electro-beam machining. Die Sinking Electrical discharge machining does not necessitate any medium for the transfer of energy. There are different aspects that have to be considered before choosing any NCM process e.g. features of work materials, shapes to be machined, process capacities, physical parameters and economic consideration.

V. Sharma and S. Kumar in [7] evaluate the process parameters for the choice of NCM. These processes were utilized in the optimization of any NCM procedure and these incorporate the usage of collimated mono-chromatic and more coherent light beams for evaporating and melting work materials. The choice of NCM process incorporates the identification of work materials and the form of machining procedure to be done. Much attention is paid to the features of work materials e.g. thermal resistance, hardness, chemical inertness, strength to weight ratio, electrical conductivity and life expectancy. These features are to be higher for effective machinability.

F. Talib and M. Asjad in [8] argued that among different NCM process, ultra-sonic machining has the best capacity and is more versatile as both conductive and non-conductive, complicated and brittle in shape, which can be machined with significant precision. These are two various classes in laser beam machining: laser milling and laser micromachining. In the plasma-arc machining, very high temperature plasma arcs are generated to eliminate materials in plasma arc machining procedures.

B. Damian, K. Daniel and M. Piotr in [9] evaluated the electro-chemical deburring machining, which is a process that incorporates the removal of materials using electro-chemical erosion and electro-chemical dissolution. It uses the discharge from electricity in electrolytes for the elimination of materials that aids in accomplishing high rates of material removal. NeerajGoyal in [10] concluded that the choice of NCM process is based three fundamental parameters: machining operations, process features and workpiece materials.

NCM process choice arises with respect on the identity of different types of materials in a workpiece and the different forms of machining operations that have to be done. Most research have focused works on NCM process, some of them have presented theories and systematic processes of selection of NCM processes.

F. Talib and M. Asjad in [11] have proposed a 'choice' process for NCM processes with respect to the combination of 'analytic hierarchy' and the methods for order inclination that connects the similarities to ideal solution techniques. Analytic hierarchy methods are utilized to evaluate the technique for weight, which represents the relative importance of the approach, whereby methods for order inclination that connects the similarities to ideal solution techniques are utilized to rank every viable NCM procedures.

S. Das and S. Chakraborty in [12] presented a schematic approach for the 'choice' of the most viable NCM process that is constrained of machining and material conditions. The researchers also projected the application of interlinked approaches based on analytic hierarchy methods and methods for order inclination that connects the similarities to ideal solution techniques. These methods are utilized in the choice of the most fundamental NCM procedure for particular workpiece materials and the characteristics of shape combinations.

A. Hashemi, M. Dowlatshahi and H. Nezamabadi-pour in [13] have identified the application of the most recent MFDM approach, which is multi-objective optimization of the NCM procedures with respect of ratio analysis approach to mitigate various MFDM issues in manufacturing ecosystems, incorporating NCM selection issues. The researchers also projected the application of analytic network method to select the most specific and applicable NCM process for a certain machining application with respect to feedback and interdependency relations among various criteria influencing NCM process 'choice'.

G. Farantos in [14] initiated the application of 'information envelopment analysis' method for mitigating NCM 'choice' issues. The researches considered mitigating two-case researches and the findings obtained were considered adaptable, versatile and applicable to NCM 'choice' approaches. The researchers also structured a remedy for choosing four different NCM processes based on the application of integrated ''Preference Rank Organizational Methods for Enriching Evaluations' (PROMEE) and the 'Geometrical Analysis for Enrichment Evaluation' (GAEE). The researchers also concluded that potentiality, suitability and applicability of 'assessment of mixed information' approach for mitigating NCM process 'choice' issues, was critical.

Section IV below focusses on various machining operations for NCM and 'approaches' with respect to the above mentioned parameters.

IV. CRITICAL ANALYSI: SELECTION OF NCM PROCESS

Various NCM Operations

Complex designed products can be produced based on work piece materials based on the application of the best NCM procedures.

- Deep cutting: The operations of machining are done to produce desired designs on the workpiece materials with more cutting depth.
- Shallow cutting: In these operations, the cutting depth is considerably low.
- Drilling operations: The operations are utilized to machine or cut holes of spherical cross-sections in solids.
- Precision cavities: The cavity with closer dimensional tolerance is provided for inner application.
- Standard cavities: The cavity with more clear dimension set is produced; however, it cannot be employed for more intrinsic application.
- Double contouring: The feature of shape obtained is demarcated into two different and separate, bottom and top contours of workpiece materials.
- Surface revolution: The operations are completed to obtain the best surface finish on workpieces through the rotation of workpiece in 2D curve about an axis.
- Finishing: These machining operations are completed to accomplish mirror finish on surfaces of workpieces with higher surface finish and high accuracy.

Process Features

In NCM, some of the process features have a direct implication on effectiveness and productivity of NCM processes. These features incorporate: Potential Difference (PD) is applicable to the operation of NCM set-up:

- Corner radius (units: mm): Circle radius, which is generated if the arc corners of the rectangle has been extended to create a complete circle.
- Overall cost: This is the total costs in NCM set-up and incorporates the costs of tooling, energy consumption, tool wear cost and fixture.
- Current features in (A): To initiate the removal of materials in NCM, there has to be a flow of electronic circuits.
- Volumetric rate of removal of materials (mm3/min): The overall volume of materials removed from the workpieces in every unit machine time
- Energy rating in (W): The energy rating of NCM setup
- Safety scale in (R): Safety denotes to the operation safety whereas performing machining operations in NCM equipment.
- Surface damages in (mm): Damages by workpiece surfaces is due to the imperfect machining and the implication force that acts on the workpiece during the process of machining or due to ion beam bombardments.
- Surface finish in (mm): This is the allowed deviation from flat surfaces that can be attained through actions of machining and it is measured based on the centerline mean or roughness mean value.
- Taper in (mm/mm): This represents a slow narrowing of workpiece from references towards a single end of workpiece.
- Tolerance in (mm): This is the dimensional closeness of the products whenever contrasted with surface specification.
- Toxicity: Toxicity represents the ecological hazards because of machining medium contaminations.

Choosing Machining Processes

Operation Competitiveness Rating Analysis (OCRA)

OCRA approach was developed to aid in the choice of a critical NCM procedure for particular machining applications based on various quantitative and qualitative methods e.g. tolerance and surface finish, tool consumption, tooling and fixture, power requirements, material removal, and shape features among others. OCRA approaches MFDM approaches that are fundamental for evaluating relative performances for the gathering of competitive alternatives. Major enhancement of OCRA method is that it deals with MFDM status whenever the relative weight of these approaches are referenced from the different alternatives and distributions of weights allocated to the approaches of these alternatives. In addition, some approaches are not precise to alternatives.

The approach is advantageous for minimization and maximization method separately. This condition aids the makers of decisions not to lose data during the process of making decisions. Other improvements in OCRA approaches incorporate non-parametric approaches (i.e. calculation of the process is not influenced by the advent of novel parameters). The main advantages of OCRA is to underpin independent evaluations of these alternatives with respect to different methods (both advantageous and disadvantageous); and finally to connect two different segments meant to achieve operational competitive rating.

Quality Functional Development Processes (QFDP)

The Quality Functional Development Processes (QFDP) represents a process developed to aid in the transformation of the customer voice into engineering features for products. This procedure of selection of NCM process was developed and its inference brought out. QFDP represents an efficient method for product development and planning with respect to customer technical requirements. The procedure of QFDP has been mentioned in ISO—163551:2015. The concept of ‘choice’ can be utilized in the coordination to QFDP to choose promising services and products’ configurations from various alternative of modular functional development users QFDP to effective establish client requirement and identify significant design requirements with special focus on modularity.

The major objective of QFDP is to facilitate the translation of quality approaches that are subjective according to the preference of clients into an approach that is more objective. This allows makes it possible for it to be considered more standard and suitable for use in the designing and manufacturing of engineered products. QFDP represents a more systematic approach for structuring and planning engineering products. Through the adoption of data, research groups can specify the requirements of clients through the assessment every projected products in a systematic manner. This makes it easier to identify the dimension of meeting consumer expectations. Implementations of QFDP incorporate the formation of ‘house of quality’ matrix.

QFDP’s basic features are to issue better judgement among various methods that will be easier to examine the methods affecting the choice of the best NCM process. Product features that have to be considered for NCM processes are Workpiece materials, shape features, surface finishes, minimal surface damages, corner radii, production period and production economy. To avoid repetitive evaluation, all the product features mentioned above have to be considered independent of every feature. Since product-features can have various values, the application of analytical hierarchy becomes fundamental to evaluate weight of individual product features. NCM process ‘choice’ decision is based on the dimension to which process features are capable of meeting desired product features.

In the regard, the process features that are obliged for attaining the essential product features are:

- Application of materials: This focusses on the frequencies at which certain NCM procedures have to be utilized for a particular material.

- Shape applications: This indicate the capacity of NCM process for the production of particular shapes on particular items.
- Capital investments: It is the overall initial costs and relative investments required for NCM process installation.
- Fixtures and tooling: In case NCM processes require replacement of a particular fixture or tooling, therefore it can be encrypted under specific product element.
- Requirements of energy: This represents the ratings of energies within a particular NCM procedure.
- Efficiency: It represents the applicable ratio of the amount of energy and the removal of materials on NCM over the overall energy amount release to machines.
- Process ability: This represents the ability of particular NCM procedures to attain significant accuracy and surface finish, handle surface damage depths and maximum material removal rates
- Tool consumption: This feature handles the aspect of tool-transforming requirements for machining particular engineered products and handles the costs incorporating it.

I. Ihara, D. Burhan and Y. Seda in [15] utilized a 16-digit grouping code to evaluated ineffective NCM processes from ranks of the remainder efficient procedure. The researchers also structured a multi-feature selection process incorporating the methods of performing orders with respect to the same remedy idea and procedures of analytic hierarchy to aid in the manufacture personnel in evaluating suitable NCM procedures for particular application requirements. The researchers also structured the analytical hierarchy expert scheme that has a graphical interface for NCM process selection. This interface will rely on the logic table to potentially discover the processes of NCM in the acceptability zones, and then choose the most effective process with higher acceptability index. The researchers also projected the usage of QFDP-based approach to ease the optimal NCM procedure selection process.

D. Baric and M. Starcevic in [16] structured an expert scheme that utilized analytic hierarchy approach for choosing the most effective NCM process for certain work materials and features of shapes. These analysts also built a web-based knowledge centre schemes that can identify the most effective NCM process to outline particular circumstances based on the requirements for input parameters e.g. the type of materials, shape application, process economic and other process capacities, such as tolerance, length-to-diameter ratio, width of cut, corner radius and surface finish.

S. Mekid in [17] presented a diagraph methodology that mitigates the issues of NCM process choice, considering an aid of graphical interfaces and audio-visual assistance. The researchers also initiated an analytical network procedure to choice the most effective NCM processes for certain machining applications based on feedback relationship and dependency among different methods influencing NCM process 'choice' decision. The analytical network procedure and solver was structured to systemize the complete NCM procedure 'choice' decision procedure.

A. Charnes and W. Cooper in [18] applied the input minimized model known as Charnes, Cooper and Rhodes (CCR) of information envelopment evaluation meant to shortlist the efficacy of NCM procedures for a particular application and therefore engage weighted-general efficacy ranking approach to rank efficient procedures. The researchers also used a multi-objective aspect of optimization with respect to ratio analysis, which is an approach for choosing the most effective NCM procedure for certain materials of work and combination of shape features. These analysts also utilized the GAEE for NCM process 'choice' for a particular machining application.

M. Alam and R. Goyal in [19] have applied the reference point approach for selecting the most effective NCM procedure for generating cylindrical holes on titanium and cavities on ceramics. The researchers also explored the application of assessing mixed information, which is an approach for mitigating NCM process 'choice' issues. The researchers also projected a decision support model to evaluate possibilities of seven various NCM processes in cutting procedures of carbon structural steel that has a plate with width of 10 mm. A model for decision-making is therefore developed to minimize the available gap between the forecast of the most effective NCM process and the actual-time machining requirement.

QFDP Development: NCM Process 'Choice' Framework

The significance of the weight of every technical requirement can be evaluated using a simple mathematical approach, whereas identifying the connection between the various factors. These clients' requirements are incorporated along with the rows of the HOQ matrix. Costs, safety and workmaterials are considered as technical requirements (process features) for developed HOQ matrix in the NCM process selection. These are then shortlisted after considering the valuable comments from process experts and after detailed evaluation of the past research assumptions. In HOQ matrix, both the beneficial and non-beneficial features of the clients' requirement are noted using the correspondent development driver value (i.e. -1) for the beneficial approach and (-1) for the non-beneficial approach. Therefore, among the considered product features, the costs of machining, power consumption and tool wear are considered as non-beneficial features, which typically require minimal values for the choice of the best NCM process.

Contrary to that, in the HOQ matrix, energy requirement and the costs are identified as non-beneficial process features. In HOQ, relative significance (i.e. priority) of the product features can be assessed based on the application of fuzzy priority scales with triangular membership functions that has a scale value of 1.0 (not significant), 2.0 (significant), 3.0 (much more significant), 4.0 (very significant) and 5.0 (most significant). For filling the HOQ matrix and structuring interrelationship matrix between product features and process features, fuzzy priority scale is projected as: 1 (significantly weak), 2 (very weak relations), 3 (weaker relations), 4 (weak relations), 5 (moderate relations), 6 (strong relations), 7 (stronger relations), 8 (very strong relations) and 9 (significantly strong relations). These triangular fuzzy values for giving relative significance are later defuzzified based on the application of centroid approach.

Whenever the HOQ matrix has been filled with the essential data, weight for every process features is correctly computed based on the following:

In the NCM process 'choice' framework, the following NCM processes, shape characteristics and work materials are considered with respect to the most effective NCM process to attain a particular machining application.

- NCM process: chemical machining, abrasive jet-machining, electron-beam machining, electric and chemical machining, electro-discharge machining, laser-beam machining, and plasma-arc machining, ultrasonic machining, and water-jet machining.
- Work materials: glass, ceramics, plastics, refractories, titanium, super alloys, steel and aluminum.
- Shape characteristics: shallow-through cuttings, deep-through cuttings, double contouring, surface revolutions, precise smaller holes with diameters less than 0.025 mm, precise smaller holes with diameters greater than 0.024 mm, more standard holders with l per d ratio, which is less or equal to 20.50 and l per d equal to the slenderness ratio. A standard hole with l per d ratio is 20.50.

Techniques for Order-Inclination connecting Similarity to Ideal Solutions and Analytical Hierarchy approach

An integrated methodology of Techniques for Order-Inclination connecting Similarity to Ideal Solutions and Analytical Hierarchy approach helps in deciding the most fundamental factors influenced by decision makers during the task implementation stage. As for the method of Techniques for Order-Inclination connecting Similarity to Ideal Solutions, through the completion of simple tasks, an idea solution is found to potentially achieve an optimized remedy. In Techniques for Order-Inclination connecting Similarity to Ideal Solutions, approaches in association with analytical hierarchy complete the complete MFDM procedure that deals with both the objective and subjective aspects.

The last step of Techniques for Order-Inclination connecting Similarity to Ideal Solutions provides us with the alternatives based on the descending preference order. For evaluating normalized matrix based on the techniques, it is fundamental to consider both subjective and objective estimates for every attribute as potential alternatives. Once we achieve all the values of the decision matrix, we can continue with more processing steps. Similarly, when computation of the typical matrix is done, normalized and weighted matrix is found out where relatedness of attributes has been accustomed by analytical hierarchy.

MFDM aids the makers of decision to identify the most effective alternative from a fixed collection of choices. MFDM approach has been used widely in the choice of work-materials, vibrant prototyping procedures, thermal energy plants, industrial robotic systems, assessment of projects, mobile phones, designing of products, flexibility of manufacturing systems, and performance measurement frameworks for manufacturing firms, plant layout designs and other essential fields in engineering. Techniques for Order-Inclination connecting Similarity to Ideal Solutions have been established based on the identification of ideal values and negative idea values based on the nearest ideal value, which is considered in the process design.

Analytical hierarchy process can effectively evaluate both the tangible and non-tangible remedies by processes of subjective evaluation of various individuals during the process of decision-making. Techniques for Order-Inclination connecting Similarity to Ideal Solutions is a method that deals with tangible attributes and the alternatives that have to be evaluated. Techniques for Order-Inclination connecting Similarity to Ideal Solutions need the application of more powerful method to determine the relative significance of various characteristics based on the objectives and final products, which can be attained by analytical hierarchy e.g. processes. In that case, to utilize both the methods (Techniques for Order-Inclination connecting Similarity to Ideal Solutions) an integrated MFDM is utilized to choice the most effective NCM process.

Information envelopment analysis was done in 1978 to determine the change of fractional linear efficiency measurement to linear programming format. In this case, decision-making units could be evaluated based on multiple inputs (non-beneficial features) and the outputs (beneficial features), even when the production functions are not identified. Information envelopment analysis is an approach utilized in evaluation relative efficiency based on the application of multiple outputs and inputs without any priori data concerning the outputs and inputs that are significant in determining the effective scores. Non-parametric methods mitigate linear programming formation in every DMU and the weights allocated to every linear aggregation and the results that correspond to linear programming. The weights are considered significant and used to shortlist a particular DMU based on the restrictions that no other form of DMU provides the same weights or something more than 100%.

Consequent to that, Pareto Frontier is accomplished and determined by a particular Decision-making unit on the boundary envelope of the output-input variable space. Frontier is viewed as a sign of relative effectiveness that can be attained by about a single Decision-making unit. An effective alternative incorporates relative efficiency score of 1, which shows that none of its outputs can be enhanced without developing the inputs or diminishing the outputs. Information envelopment analysis was started as a mathematical programming framework that was applicable to observation information that provided a new approach used to obtain empirical assessment of external connections such as efficient production surface possibility that represent a foundational stone of the current economic condition.

Information envelopment analysis has now become one of the most effective and fast developing segments of operational research and management science over the past few decades. Because on the advancements in technology and engineering and with the continued development of harder and novel materials, attention has to be paid to NCM processes to machine the materials with low machinability features. For the generation of a particular shape characteristic onto particular work materials, the most effective NCM process has to be chosen from the collection of alternative processes with diversified machining features.

V. CONCLUSION AND DISCUSSION

In conclusion, this research contribution has used the Copper and Rhodes model of Data Envelopment evaluation to potentially identify effective NCM processes that represent certain shape features and combinations of work materials. In this case, MFDM approach is applied to effectively rank these effective NCM process in a descending order based on priority. To choose the most effective NCM process for producing a particular shape characteristic on a particular work material, four aspects of machining has to be considered: Physical parameters, features of work materials and the shape feature dimensions that need machining, process capacities, economy considered all the requirements.

In this research paper, criteria and attributes, which affect NCM process 'choice' decision, incorporate:

- Tolerant surface finish: It considers the machining capacity of NCM process considering the manner in which NCM process can closely maintain tolerance and attain the essential surface finish on the work materials. Surface finish is determined based on the centerline mean or Ra-value, which is recorded in microns.
- Power requirements: It connects with the energy ratings of the equipment and machines for a certain NCM process in kW.
- Material removal rates: It determines the material amount (in mm) that has been removed from the workpieces by a certain NTM procedure in every unit time. The effectiveness of NCM process is directly proportional to the material removal rates.
- Costs: This aspect considers the initial costs of acquisition and the kind of investment requirement for the installation of the NCM process with respect to the equipment and machines for a particular machining application.
- Efficacy: This represents the ration of output energy that is present for removal of the essential material amount from the workpiece to the input energy for a particular NCM process.
- Fixture and tooling: It considers the costs of fixture and tooling, which requirement replacement every time in a certain NCM process.
- Tooling consumptions: This is the integrated costs of tool change for a certain NCM process, even though it does not focus on the time needed for these tool changes.
- Safety: It is connected to the machine operation safety for a particular NCM process. It also considers toxicity, medium of machining and contaminations.
- Work materials: It majorly focusses on how easier certain NCM processes can machine a particular materials and the manner in which NCM processes can be utilized in a material.
- Shape features: This reflects on the machining capacity of a certain NCM process to produce the most desired shape features of a particular work material.

As such, for effective application of the capacities of various NCM process, critical 'choice' of the most effective process for a particular machining application should be followed. The choice of the most effective NCM process for work materials and shape feature integration necessitates the usage of different criteria. In this paper, OCRA approach produces the best correlations with assumptions from past researchers. It is thus noted that the approach can validate its significance whereas mitigating complex NCM process 'choice' issues.

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