# Selection of Non-Conventional Machining Process Considering Machining Processes by using Additive Ratio Assessment - Approach

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## ABSTRACT

Many of the recent developments in the Aerospace and Nuclear Engineering industries are partly due to the increasing use of difficult – to – machine materials. Many of these materials also find application in other industries owing to their high strength- to weight ratio, hardness and heat resisting qualities. Non-traditional machining (NTM) processes have been developed over the past few decades. These processes are capable of generating intricate and complex shapes with high degree of accuracy, close dimensional tolerance and better surface finish. The right choice of the most appropriate NTMP is critical to the success and competitiveness of a manufacturing company. Selection of the most appropriate NTMP for a given machining application can be viewed as a multi criteria decision making process. This paper focuses on additive ratio assessment (ARAS)-based method dealing for the selection non-conventional machining processes for the machining of complex shapes. A complete list of all the non-conventional machining process from the best to the worst is obtained, taking into account multi-conflicting machining of various attributes. To obtained complete ranking performance of the non-conventional process.

**Keywords:** Non-Traditional Machining Processes, Multi Criteria Decision Making Processes-Additive Ratio Assessment Method.

## I. INTRODUCTION

In today's highly competitive manufacturing industries often requires advance and new materials with high strength, density, strength, stiffness, hardness, toughness, creep resistance impact resistance and with other challenging mechanical properties. In the recent years there has been increasing usage of materials in large quantities due to the development of material science such as Aluminum, Steel, Super alloy, Titanium, Refractories, Ceramic, Plastic, Glass and other materials. Machining of these materials by conventional machining processes give rise to many problems such as time consuming, high cutting force, change in temperature, severe tool wear , residual stresses generated in the work piece and less dimensional deformity due to strain hardening. Moreover conventional machining processes are not suitable for these materials as the desired level of accuracy and surface finish cannot be easily achieved. From these reason, during past years, there has been a wide application of called non-conventional machining processes. The Non-Traditional Machining processes are classified according to the nature of energy, employed in the machining. Such as Thermal and Electro thermal, Chemical and Electrochemical and Mechanical, are utilized for material removal from the workpiece. In chemical machining (CHM) process and electrochemical machining process, material is removed by anodic dissolution in an electrolytic medium in which the workpiece is the anode and the tool is the cathode, which is in contact with a chemically active reagent. Additionally, two or more forms of energy are combined together to develop hybrid Non Traditional Machining processes in order to enhance the machining capabilities. Material removal in electrochemical type of Non Traditional Machining processes is carried out through ion displacement mechanism, which requires high current as the source of energy and electrolyte as the transfer medium. Those processes includes Chemical machining (milling and blanking), Electrochemical Machining (ECM), Electrochemical Grinding (ECG), Electrochemical Honing (ECH) and Electro chemical Deburring (ECD).

For Thermo-electrical type of Non- Traditional Machining processes, the thermal energy is employed to melt or vaporize of the small areas at the surface of the workpiece by concentrating the heat energy on a small area of the material. The source of energy utilized can be high voltage, amplified light or ionized material. Thermo-electrical processes methods include Electrical Discharge Machining (EDM), Wire EDM (WEDM), Laser Beam Machining (LBM), Electron Beam Machining (EBM), Plasma Arc Machining (PAM), and Ion Beam Machining etc. In mechanical methods of Non Traditional Machining processes, material removal takes place due to mechanical erosion of the workpiece material, while employing high velocity particles as the transfer media.

The mechanical method includes Ultrasonic Machining (USM), Abrasive Jet Machining (AJM), and Water Jet Machining (WJM). The application of the non – traditional machining processes are also influenced by the workpiece shape and size to be produced, viz. holes, through holes, through cavities, through cutting, and special applications. A qualitative assessment of different non-traditional machining processes, taking into consideration part shape and given in the Table 1.

The following machining operations are taken into consideration in the present decision guidance framework:

- ✓ Deep cutting – This machining operation is carried out to generate the desired shape feature on a workpiece material with higher depth of cut (greater than 40 μm).
- ✓ Precision cavity – In this machining operation, cavity with close dimensional tolerance (±50 μm) is generated for intrinsic applications.
- ✓ Standard cavity – Cavity with explicit set of dimensions is generated, but cannot be employed for intrinsic applications.
- ✓ Shallow cutting – In this machining operation, the depth of cut is comparatively low (less than 40 μm).
- ✓ Double contouring – The shape feature generated by this machining operation is defined by two separate and different, top and bottom contours of the workpiece.

These processes work on particular principles by making use of certain properties of materials which make them most suitable for some applications and at the same time put some limitations on their use. The Multi Criteria Decision Making (MCDM) can be generally described as the process of selecting one from a set of available alternatives, or ranking alternatives, based on a set of criteria, which usually have a different significance. MCDM was one of the fastest growing areas of operational research and because of them MCDM methods have been proposed.

From many of the proposed MCDM methods, we shall state some of the most prominent, such as Simple Additive Weighting (SAW) Method, Analytic Hierarchy Process (AHP) method, Technique for Ordering Preference by Similarity to Ideal Solution ( TOPSIS ) method, Complex Proportional Assessment

( COPRAS ) method , Additive Ratio Assessment ( ARAS ) method. Thus, the non – traditional machining processes can be regarded as a multi-criteria decision making problem for which a logical and systematic selection approach is required for identifying the best alternative.

The non – traditional machining processes task lies in comparing the property of a feasible set of alternative machining processes and selecting the best one out of this set. But while choosing a non – traditional machining processes for a engineering application, the designer usually apply trial and error methods or employ their knowledge and perception which may fail at instance. So for selection of non – traditional machining processes, an efficient and organized approach, based on some strong mathematical foundation, is thus required to make sure the integration between design and manufacturing objectives.

The actual performance of a particular non – traditional machining process under different conditions may differ from the expectations. In this paper the application of recently developed multi criteria decision making method has been used that is the additive ratio assessment method for selecting the most appropriate non-conventional machining process considering machining application.

## II. ARAS METHOD

A new additive ratio assessment method was proposed by Zavadskas and Turskis 2010. Therefore the ARAS method can be classified as a newly formed, but effective and ease to use, MCDM method. The ARAS method has been applied to solve various decision making problems, and also have been formed its fuzzy and grey extension, named ARAS-F and ARAS-G

Based on Stanujkic and Jovanovic 2012, the procedure of solving problems by using ARAS methods, in cases when MCDM problem include only benefit criteria, can be precisely described by using the following steps

Step1. Determine optimal performance rating for each criterion.

After creating a decision matrix, the next step in the ARAS method is to determine the optimal performance rating for each criterion. If decision makers do not have preferences, the optimal performance ratings are calculated as.

$$x_{0j} = \frac{max}{i} x_{ij},$$

Where $X_{oj}$ is optimal performance rating in rating in relation to the $j^{th}$ criterion.

Step 2. Calculate the normalized decision matrix

$$R = [r_{ij}].$$

The normalized performance ratings are calculated by using the following formula.

$$r_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}},$$

Where $r_{ij}$ is the normalized performance rating of the $i^{th}$ alternative in relation to the $j^{th}$ criterion.

Step 3. Calculate the weighted normalized decision matrix

$$V = [v_{ij}]$$

The weighted normalized performance ratings are calculated by using the following formula

$$v_{ij} = w_j \times r_{ij},$$

Where $V_{ij}$ is weighted normalized performance rating of $i^{th}$ alternative in relation to the $j^{th}$ criterion.

Step 4. Calculate the overall performance index for each alternative.

The overall performance index $S_i$, for each alternative, can be calculated as the sum of weighted normalized performance ratings, using the following formula

$$S_i = \sum_{j=1}^{n} v_{ij},$$

Step 5. Calculate the degree of utility for each alternative. In the case of evaluating faculty websites, it is not only important to determine the best ranked website. There is also important to determine relative quality of considering websites, in relation to the best ranked websites. For this we use degree of utility, which can be calculated using the following formula

$$Q_i = \frac{S_i}{S_0},$$

Where Qi is degree of utility of i [th] alternative, and $S_0$ is overall performance index of optimal alterative, and it is usually 1.

Step 6. Rank alternatives and/ or select the most efficient one. The considered alternatives are ranked by ascending $Q_i$, that is the alternatives with greater values of $Q_i$ have a higher priority rank and the alternatives with the largest value of $Q_i$ is the best placed.

**Table 1.** Non-Conventional Machining Process For Applications

| | **Small Holes 0.15 < D < 0·03** | **Shallow L/D < 20** | **Deep L/D > 20** | **Precision** | **Standard** | **Shallow** | **Deep** | **Double Contouring** |
|---|---|---|---|---|---|---|---|---|
| **USM** | - | GOOD | POOR | GOOD | GOOD | POOR | POOR | POOR |
| **AJM** | - | FAIR | POOR | POOR | FAIR | - | - | - |
| **ECM** | - | GOOD | GOOD | FAIR | GOOD | GOOD | GOOD | GOOD |
| **CHM** | FAIR | - | - | POOR | FAIR | GOOD | POOR | - |
| **EDM** | FAIR | GOOD | FAIR | GOOD | GOOD | GOOD | GOOD | FAIR |
| **EBM** | GOOD | FAIR | POOR | POOR | POOR | - | - | - |
| **LBM** | GOOD | FAIR | POOR | POOR | POOR | - | - | - |
| **PAM** | - | FAIR | - | POOR | POOR | - | - | - |

**TABLE 2.** INITIAL DECISION MATRIX

| | Small Holes 0.15 < D < 0·03 | Shallow L/D < 20 | Deep L/D > 20 | Precision | Standard | Shallow | Deep | Double Contouring |
|---|---|---|---|---|---|---|---|---|
| **USM** | 0 | 7 | 3 | 7 | 7 | 3 | 3 | 3 |
| **AJM** | 0 | 5 | 3 | 3 | 5 | 0 | 0 | 0 |
| **ECM** | 0 | 7 | 7 | 5 | 7 | 7 | 7 | 7 |
| **CHM** | 5 | 0 | 0 | 3 | 5 | 7 | 3 | 0 |
| **EDM** | 5 | 7 | 5 | 7 | 7 | 7 | 7 | 5 |
| **EBM** | 7 | 5 | 3 | 3 | 3 | 0 | 0 | 0 |
| **LBM** | 7 | 5 | 3 | 3 | 3 | 0 | 0 | 0 |
| **PAM** | 0 | 5 | 0 | 3 | 3 | 0 | 0 | 0 |

**TABLE 3.** NORMALIZED DECISION MATRIX

| | Small Holes 0.15 < D < 0·03 | Shallow L/D < 20 | Deep L/D > 20 | Precision | Standard | Shallow | Deep | Double Contouring |
|---|---|---|---|---|---|---|---|---|
| **USM** | 0.0000 | 0.1313 | 0.0562 | 0.1313 | 0.1313 | 0.0562 | 0.0562 | 0.0562 |
| **AJM** | 0.0000 | 0.0938 | 0.0562 | 0.0562 | 0.0938 | 0.0000 | 0.0000 | 0.0000 |
| **ECM** | 0.0000 | 0.1313 | 0.1313 | 0.0938 | 0.1313 | 0.1313 | 0.1313 | 0.1313 |
| **CHM** | 0.0938 | 0.0000 | 0.0000 | 0.0562 | 0.0938 | 0.1313 | 0.0562 | 0.0000 |
| **EDM** | 0.0938 | 0.1313 | 0.0938 | 0.1313 | 0.1313 | 0.1313 | 0.1313 | 0.0938 |
| **EBM** | 0.1313 | 0.0938 | 0.0562 | 0.0562 | 0.0562 | 0.0000 | 0.0000 | 0.0000 |
| **LBM** | 0.1313 | 0.0938 | 0.0562 | 0.0562 | 0.0562 | 0.0000 | 0.0000 | 0.0000 |
| **PAM** | 0.0000 | 0.0938 | 0.0000 | 0.0562 | 0.0562 | 0.0000 | 0.0000 | 0.0000 |

**TABLE 4.** RANKING OF NON-CONVENTIONAL MACHINING PROCESSES

| | $S_i$ | $U_i$ | RANK |
|---|---|---|---|
| **USM** | 0.6187 | 65.97 | **3** |
| **AJM** | 0.3 | 31.99 | **6** |
| **ECM** | 0.8816 | 93.99 | **2** |
| **CHM** | 0.4313 | 45.99 | **4** |
| **EDM** | 0.9379 | 100.00 | **1** |
| **EBM** | 0.3937 | 41.98 | **5** |
| **LBM** | 0.3937 | 41.98 | **5** |
| **PAM** | 0.2062 | 21.99 | **7** |

## III. RESULTS AND DISCUSSION

In this paper recently developed MCDM method, i.e. ARAS method was applied for the purpose of multi-criteria economic analysis of various, Non-Traditional machining processes considering eight different machining operations criteria are discussed.

In this paper, the 10 point scale is considered suitability for non-conventional machining processes and with respect to different machining processes. Thus the value of 0 was assigned to non- conventional machining process which are not possible to machine using the machining process. On the other hand value of 7 was assigned to non- conventional machining process which has good machining performance. Similarly the value of 5 and 3 are assigned to non-conventional machining process which has fair and poor machining performance respectably. Thus the initial decision matrix is shown in Table. 2.

In this method, from the normalized decision matrix, the weighted normalized matrix is first developed, as shown in Table 3. Next using, the optimality function Si for each off the non- conventional machining process alternative is calculated. Then the corresponding values of the utility degree Ui determined using 08 for all the alternatives. The utility degree weighs each alternative with respect to the most efficient one. These utility values offer a comprehensive ranking of the considered non-conventional machining process alternatives. Higher the value Os Si and Ui and the ranking achieved by the materials are displayed in Table 4.

It is revealed from the Table 4. The obtained ranking of NTM processes for generating a through cavity on super alloys is EDM – ECM – USM – CHM – EBM – LBM – AJM - PAM. It is observed that EDM is the most suitable NTM process for this application followed by ECM and USM processes. It is observed that EBM and LBM process perform equally. From the obtained performance scores, it is observed that PAM process is not at all suitable for generating a through cavity on super alloys.

## IV. CONCLUSIONS

With the advancement of technology, newer materials, energy sources, manufacturing strategies, decision making procedures and management techniques are also being concurrently developed. The developed decision making procedure provides consistent guidance to the process engineer facing problem with NTM process selection decisions for varying machining applications. It incorporates an exhaustive database of NTM processes. It assists the process engineer while providing an easy access to choose various machining operations and process characteristics to finally select the best feasible NTM process along with its ideal parametric settings on a single platform. Thus, it can identify the best NTM process for a given machining application as all the considered NTM processes.

Although a good amount of research work was already been carried out by the past researchers on NTMPs selection and ranking, this paper introduces the use of ARAS method. Till date, this method has very limited applications in the machining domain.

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