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Systemic method for Abrasive Water jet Machining Process Parameters Evaluation using Error Pruning Tree Classification Technique

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Abstract-

At various parametric conditions such as Jet Pressure (JP), Cutting Distance (CD), and Cutting Speed (CS) with distinct levels using Reduced Error Pruning Tree (REPTree) in Decision Tree (DT) classification, an attempt was made to estimate the abrasive water-jet system process properties on $AlSi_7$/SiC composite. In DT learning, the REPTree classification algorithm is used as a representative strategy. Machining input parameters such as JP, SOD, CS of the DT are independent of the simple algorithmic properties of the process. Subtree structures that can be replaced by a leaf node with class mark and attribute values that are independent of each other with the help of DT under consideration. The idea of a uniform tree analysis that leads to the pruning of the number of subtrees is extended to the tree. The proposed strategies minimize computing costs, improve the speed and precision of the performance of the device.

Keywords: $AlSi_7$/SiC composite; Abrasive water-jet machine; Classification; Decision Tree; Reduced Error Pruning Tree

Introduction

Ductility, solid conductor, light weight, high strength, and superior capacity-resistant load, aluminium is considered to be paying heed to other materials on the market [1-3]. Once aluminium and low density material mix to form metal matrix composites with hard particles such as ceramics, they will have enhanced properties and will be used in a wide range of manufacturing and structural fields such as maritime, automotive, military, etc [4-6]. The basic purpose of introducing the composite particle is to have superior strength in the weight-to-weight ratio and to improve composite stiffness [7-9]. The matrix governs the international properties of the composites, and it also affects the composite's temperature to strength ratio [10]. In the matrix, the reinforcing direction strongly determines the composite property [11,12]. Consequently, the particle size and form would also play a crucial role in determining the composite property, irrespective of the option of the right reinforcement in the matrix [13-15]. Any of the structural defects such as agglomeration, oxide inclusions, white areas of interfacial reaction between the components in the mixture occur unsatisfactorily throughout the casting process [14-16]. In order to overcome these defects, several new methods and modifications have been applied to the usable traditional casting process [17]. For e.g., the ultrasonic technique is implemented when little vibration is provided in the form of kilohertz. Vibration tends to evenly disperse particles throughout the mixture, decreasing porosity and substantially reducing the other defects in the casting that usually exist in the usual traditional process [18]. Stir casting has proven to be the cheapest and easiest way to manufacture the composite material among the processing techniques available. Due to the uniform distribution of reinforcement in the mixture [19,20], the latest stir casting technique assisted by ultrasonic is an effective technique.

The property and the relation between this reinforcement and the base matrix have been reported to be excellent and a wide variety of applications are seen in the different engineering domains [21]. However, reinforcement is added to this component, e.g. aluminium oxide, for reinforcement in aluminium metal matrix composites has been shown to be less necessary than reinforcement in other ceramic materials, e.g. silicon carbide. It is observed to be considerably lower compared to ceramic reinforcements because of the improved property due to the efficiency of the material. It is very obvious from the above statement that the reinforcement alternative positions the applications of the composite material significantly [22-24].

It is always best to incorporate a high-density compound followed by a low-density compound as a reinforcement within the aluminum matrix structure [25]. Under the normal stochastic mechanism itself, the researchers were able to achieve a uniform distribution of particles according to methodologies [26]. In phases above 1400^{o}C, ceramic reinforcements are observed to have excellent high thermal resistance, corrosion resistance, chemical inertia, and no transformation content. Ceramic particles act as a thermal shock resistant material and is found to be used as a refractory and corrosion resistant material. As the hard particle is being machined, the introduction of soft ceramics serves as an interface coating and tends to resist crack propagation [27]. The machinable property of alumina composites increases with the inclusion with reinforcements in the matrix [28].

In addition to the input criteria, the material properties guarantee the machinability of the material in the decision. There are some limitations of AWJM, such as noisy processes and a volatile operating environment [29]. In comparison, bad operational conditions contribute to kerfs taper, while the active cut-through technology has been shown to be AWJM [30].

In the operation of the pruning point, DT is the top-down method that has been ineffective. As the resulting scale of the DT increases linearly depending on the sample size, the precision of the tree becomes lower [31-33]. The Artificial Neural Network (ANN) hybrid technique of the DT collects tensile manganese steel data and trains the data with high precision. By forecasting the life of the manganese steel plate [34], this hybrid technique was used to ensure the high precision of the industrial instrument. In order to extract information from different sources at different times, numerous machine learning algorithms have been developed [35-38]. To build and predict models with a high degree of precision, the DT from the machine learning classification algorithm is used [39]. Machining tools such as axis motors and milling head motors have been validated by this DT, also it makes an increase in machining conditions, tool life and eliminates harm to machining components [40].

During the feature selection process, the most relevant data set characteristics will be selected on their own [41]. REPTree Machine learning techniques, classification algorithm that decreases computational costs, improves machining parameter speed and efficiency. Compared to Genetic Algorithms (GA) [42] and Particle Swarm Optimization (PSO) [43], the selection of the REPTree function offers excellent productivity in many areas of study. Machine learning algorithms, such as weather forecasts, market analysis, business intelligence, transport, and machining criteria, are used to test and simulate real-world applications [44-46]. Compared to Mean Absolute Error and Root Mean Squared Error statistical measures [47], REPTree classification techniques worked on machining parameters by WEKA tools and showed an improvement in the performance of machining parameters. 3D printing technology is a revolutionary method of processing that seeks to transform the limits of the business, the activities of the organization and the supply chain [48]. Extensive work on how the most common 3D printing technology and Fused Deposition Modeling will affect updated multimedia data (FDM). The DT classification algorithm is used to decide whether the method of 3D printing is accurate or not [49]. The DT classification was shown by the process of co-crystallization embodied by hot-melt extrusion with poly (ethylene oxide) and characterized by powder X-ray diffraction, differential calorimeter scanning and infrared spectroscopy. In the WEKA software, this data collection was used to investigate the effects of temperature, screw speed, and configuration. DT provides realistic and easy-to-use instructions that illustrate how to use the approach to decision-making throughout the cycle [50].

In order to obtain the desired properties of nano-composites of PolyVinyl Chloride (PVC), fusion is a critical parameter. REPTree was developed to estimate nano-clay processing material fusion time. To classify dominant patterns in experimental performance, this data mining algorithm is used. The efficiency of the use of DT was shown as a simple information model by the data mining algorithm [51]. Measurement and wear and geometry checking of different types of roller taps designed to tap holes in micro-alloyed steel. The DT classification algorithm used to forecast the shape to tap wear at a high degree of accuracy. The numerous Data Mining techniques used to predict machining details include Multilayer Perceptron, Help Vector Machine and REPTree [52-56]. With the reduced Root Mean Square Error of the highly validated comparison methods, REPTree has the maximum degree of accuracy of modelling manufacturing and machining problems [57].

Materials and Methods

Commercially available LM-13 alloy (AlSi 7%) was fused into an induction furnace at a temperature of 725°C. At a constant stirring condition of 200 rpm, the SiC was slowly added into the vortex of the mixture. The maximum solubility of 63wt. % SiC is added at a constant stirring condition. Before adding SiC into the matrix, SiC was preheated to a temperature of 900°C and then it was introduced into the vortex. The entire manufacturing process was conducted in an argon atmosphere. After complete addition of 63% of SiC into the mixture, ultrasonic assistance is provided at a frequency rate of 2KHz. Permanent steel dies of 8mm wall thickness was preheated to a temperature of 100°C to improve the usability of the molten mixture. Finally, the composite slurry was poured into the preheated die to obtain a composite ingot of dimension 25 cm x 25 cm x 1.2 cm even after the removal of the feeder head [58, 59].

The AWJM has various parameters involved in the determination of the machining performance. Among them, the most significant parameters that have effective involvement in the prediction of the output responses alone were to be considered as the machining parameter in the present work. Cutting Speed (CS), Jet Pressure (JP), Cutting Distance (CD) is picked boundaries with three degrees of each in AWJM [60]. The picked boundaries are recorded in Table.1

Table 1 AWJM machining parameters and the ranges

AWJM / Parameters	JP (bar)	CD (mm)	CS (mm/sec)
1	220	1	20
2	240	2	30
3	260	3	40

In the world and our lives, the number of data seems ever-increasing; there is no limit to this. Computers today make it so convenient to store information. Inexpensive discs and online storage make it too convenient to postpone and maintain decisions about this content evidence. Any human decision has been documented by the information flooded by the World Wide Web (WWW). When the volume of data increases, the portion of it that people comprehend reduces alarmingly, inexorably. In data mining, the data is obtained electronically and the process is automated or at least computer-enhanced [61]. For a long time, economists, statisticians, and software engineers have been experimenting with the notion that data patterns can be tested, described, validated, and used as predictions automatically.

The concept of classification is how things are differentiated, recognized, and recalled. It involves the function of mathematical ideas and applies a classification machine learning algorithm for input data based on categories. Classification is a supervised learning approach for algorithms for machine learning in which all data sets are learned and the user is well known [62]. It was used to construct a step-by-step procedure to assess the resulting outcomes. The tree nodes reflect an input-based decision and move to the next level and the next level before a leaf that forecasts the output is reached.

A realistic, semi-theoretical sense of knowledge is needed for the new rapid increase in the discovery of data patterns that are subject to data mining. To build several trees with various iterations, REPTree uses logic. From all the trees generated, then choose the best tree and mark it as representative [63]. To measure the Mean Square Error on tree forecasts, pruning is used by the REPTree classifier. The numerical characteristics were also arranged in this manner. REPTree is the quick learning Decision Tree (DT) which constructs a tree to minimize error pruning on machining parameters through the information gain [64].

Results and Discussion

Using the Weka platform, the compilation and pre-processing of data sets will provide comprehensive support for the process of data mining, the preparation of input data, the statistical evaluation of learning processes, and the visualization of the results produced. Both machine learning algorithms take the form of a CSV or ARFF file as their content [65]. Graphic User Interface (GUI) Explorer is the easiest way of using Weka, as seen in Figure 1. This program offers access to all the algorithms for machine learning.

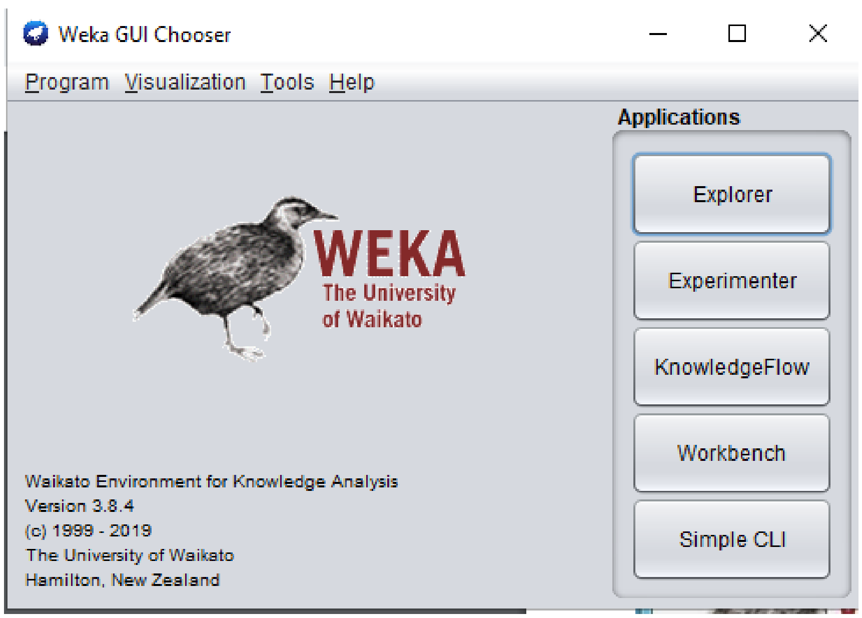

Figure 1: GUI Explorer

Algorithm of the REPTree

Step 1: If it's a numerical attribute, we need to find a break point to make it easier for each attribute A to calculate the Information Gain (IG) as seen in Equation 1.

$$IG\ (p\ ,\ n) = \frac{-p}{p+n}\log_2\frac{p}{p+n} - \frac{n}{p+n}\log_2\frac{n}{p+n} \quad \text{---------------} \ (1)$$

Where p stands for positive and n for negative.

Step 2: As seen in Equations 2 and 3, measure the IG by separated data and the Gain ratio.

$$\text{Split info (D)} = -\sum_{j=1}^{v} \frac{|D_j|}{|D|} \log_2\left(\frac{|D_j|}{|D|}\right) \text{ ------------------------ (2)}$$

$$\text{Gain ratio (A)} = \frac{gain\ (A)}{Splitinfo\ (D)} \text{ ------------------------- (3)}$$

Where D represents the data sets and the attributes are indicated by A.

Step 3: From the split information, pick the maximum IG among the attributes as an amax.

Phase 4: If IG (T, amax) > IG (T, Split info), then use the maximum value to create the tree.

Phase 5: Repeat steps 1 to 4 before the leaf node that predicts the output hits it.

Relative Absolute Error (RAE) is a way of calculating a predictive model used in machine learning algorithms for its efficiency or accuracy. Table 2 displays the AWJM experimental study on the abrasive application of Garnet.

Table 2. Experimental Analysis of Garnet abrasive

Ex No.	JP (bar)	CD (mm)	CS (mm/min)	MRR (g/s)	KA (Deg)	Ra (µm)
1	220	1	20	0.0042	0.2376	3.447
2	220	1	30	0.0055	0.1623	3.457
3	220	1	40	0.0070	0.2608	3.097
4	220	2	20	0.0047	0.3147	3.246
5	220	2	30	0.0060	0.2739	3.346
6	220	2	40	0.0083	0.3743	3.525
7	220	3	20	0.0048	0.5602	3.595
8	220	3	30	0.0067	0.6750	3.490
9	220	3	40	0.0081	0.5234	3.586
10	240	1	20	0.0046	0.5736	2.963
11	240	1	30	0.0055	0.2000	3.333
12	240	1	40	0.0084	0.2768	3.401
13	240	2	20	0.0046	0.5021	3.206
14	240	2	30	0.0064	0.3054	3.503
15	240	2	40	0.0086	0.9212	3.622
16	240	3	20	0.0045	0.7042	3.349
17	240	3	30	0.0072	0.7487	3.118
18	240	3	40	0.0099	0.7906	3.757
19	260	1	20	0.0044	0.5881	4.645
20	260	1	30	0.0059	0.5877	4.259

21	260	1	40	0.0078	0.4554	4.915
22	260	2	20	0.0043	0.5554	4.754
23	260	2	30	0.0065	0.3014	3.908
24	260	2	40	0.0083	0.5503	4.093
25	260	3	20	0.0052	0.7393	3.996
26	260	3	30	0.0068	0.3481	3.928
27	260	3	40	0.0090	0.5703	3.780

As shown in Figures 2-4, Garnet material reaction parameters of KA, MRR, and Ra was built by REPTree to scale 7, 11, 9, and 9 respectively.

KA

The REPTree is 80.20 percent of the response parameter KA with RAE, and the tree has 6 classifications. The JP root node regulates the two conditions of <250 and >=250. KA Class 1 is categorized under JP<250 and SOD<2.5, with KA Classification Observation 3 being 0.19, with 12 observations, 7 going into Meaning Class 0, and 2 falling into Subclass 0. Class 2 is classified as JP>=250, SOD>=2.5, and CS<25 with classification KA observation 5 is 0.21, from 2 observations, 2 is classified as 0 and no observation is classified as a subclass. Class 3 is subject to conditions JP>=250, SOD>=2.5, and CS>=25, with classification KA observation 6 being 0.25, with 4 observations, 2 falling into value class 0 and 2 falling into value subset 0 and so on. In observations 3, 5, 6, 9, 10, and 11, the efficiency or accuracy of the response parameter KA is high, as seen in the leaf nodes in Figure 2.

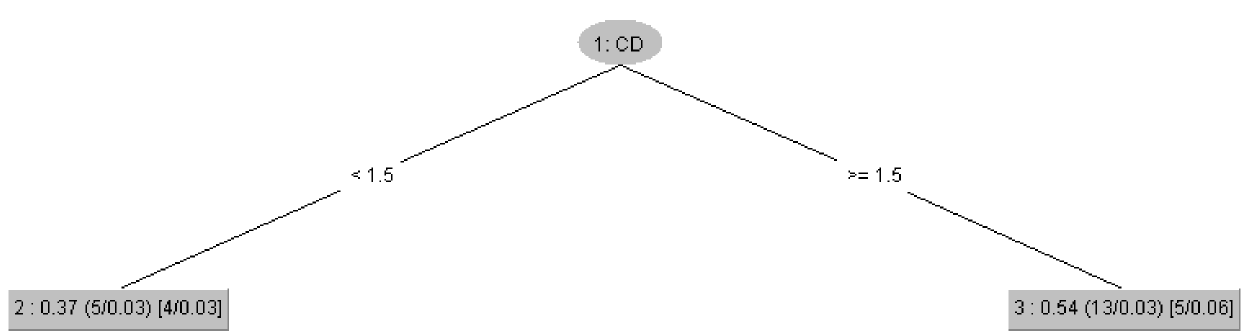

Figure 2: KA REPTree of the Garnet material

MRR

The REPTree is 79.19 percent of the response parameter MRR with RAE and there are 5 classifications in the tree. The test is repeated in SOD, CS, and JP, the same as the condition tested. In observations 3, 4, 7, 8, and 9, the efficiency or accuracy of the MRR response parameter is high, as seen in the leaf nodes of Figure 3.

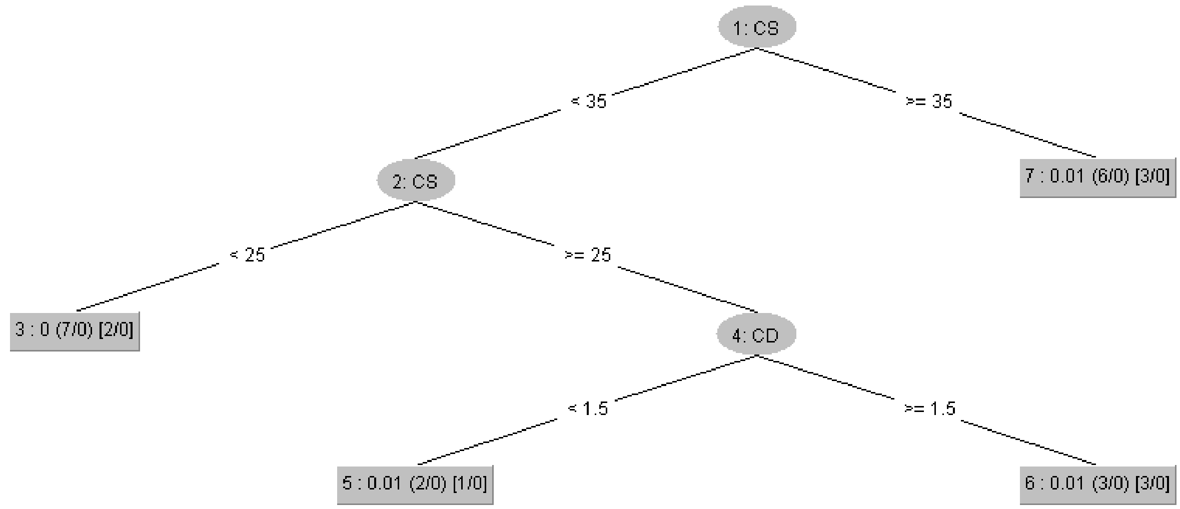

Figure 3: MRR REPTree of the Garnet material

Ra

The REPTree is 63.38 percent of the response parameter Ra with RAE and the tree has 5 classifications. The test is repeated in SOD, CS, and JP, the same as the condition tested. In observations 3, 4, 6, 8, and 9, the efficiency or accuracy of the response parameter Ra is high, as seen in the leaf nodes of Figure 4.

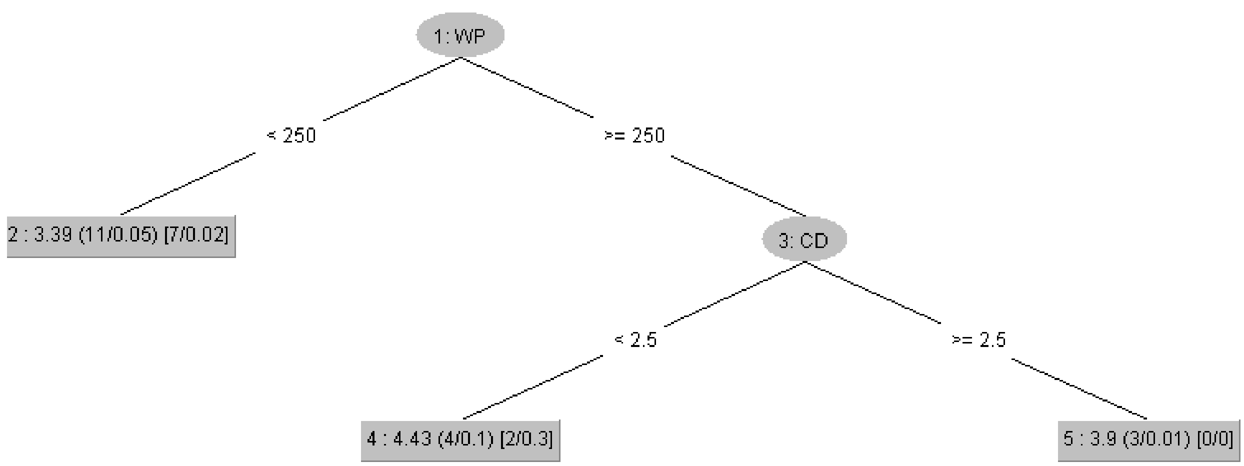

Figure 4: Ra REPTree of the Garnet material

Conclusion

Tree analysis is implemented uniformly, leading to the amount of the subtrees being pruned. The relative absolute error of the Garnet material response variables KA and MRR is larger and the tree scale is lower. Response variables Ra to the Garnet content, the size of the corresponding tree is equal. The description of the REPTree helps to reduce the noise of fittings over datasets that reduce the growth size of the tree. With the increased speed and reliability of the abrasive water-jet method, the REPTree Classification algorithm dramatically lowers computational costs.

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