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Electrochemical Micromachining of Metal Matrix Composite for Performance Investigation

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ABSTRACT: The conventional machining of AMCs is complex due to the presence of reinforcements that affects the cutting tool and surface quality of the machined components. To overcome these difficulties, non-conventional machining methods are utilized. Electrochemical machining (ECM) and chemical machining (CM) processes are thermal-free processes, but CM is applicable only for chemically conductive material. Electrochemical machining (ECM) processes play a significant role in the fabrication of micro components because of their advantages such as higher MRR (Material Removal Rate), no tool wear, good surface finish and better precision control. Electrochemical micromachining (ECMM) has been employed irrespective of difficult-to-cut materials, hard materials and tool wear; and it is one of the non-conventional non-contact machining techniques and hence, ECM is proposed for machining AMCs (Aluminium Metal Matrix Composites). The dominant parameters are selected for electrochemical machining for Al metal matrix. The parameters like voltage, current & electrolyte concentration, duty cycle are selected in order to achieve the good quality of profile cutting as well as minimum dimensional distortion.

KEYWORDS: ECMM, Aluminium Metal Matrix Composite, Material Removal Rate, Over cut

I. INTRODUCTION

The manufacturing sector explores different materials in the present time for their products, which satisfy their specific requirements. In certain applications like aerospace, automobile and shipbuilding high strength-to weight ratio is the requirement for the components. This initiated the development of newer materials with higher strength combined with lighter weight. The developments of composite materials satisfy the above requirement. The shaping of the composite materials posed a challenge, and requirements of special type of machining are inevitable. Unconventional machining solved the above problem to the larger extent. However, the quality of the machined components is mainly based on the output parameters such as Metal removal rate (MRR) and Surface Roughness (SR). Further, the above parameters are optimized to reduce the cost of the quality components.

The present study plays an imperative character in determining the optimum parameters of machining processes with respect to output parameters. The systematic method of analyzing and optimizing process parameters when composites or any material processed in unconventional machining process are explored through Design of Experiments, formation of single-objective optimization using have been illustrated in the present thesis.

II. LITERATURE REVIEW

The published literatures have been collected and reviewed carefully for exploring the status in machining process optimization of MMCs with different machining process. The collected literatures are classified into various categories such as literatures based on aluminum matrix composites, electrochemical machining, modeling and optimization highlighting the methodology adopted and the outcome of the research. The research gap has been identified after careful review of literatures, and the objectives for the present work have been derived and highlighted at the end of this chapter.

Senthilkumar et al. [1] developed the linear regression mathematical model by means of XLSTAT software. Taguchi L27 orthogonal array method with 54 trials was employed in the design of experiments. The samples were prepared in the composition of an aluminium alloy reinforced with varying SiC proportion of 5, 10, and 15 wt %. These composites were prepared by the stir casting method. NaCl was used as the electrolyte solution. While machining the composites of the cast aluminum alloy A356-SiC particles via ECM, the influence of the process parameters such as applied voltage, tool feed rate, electrolyte concentration, and percentage of reinforcement on the MRR was studied.

Pramanik et al. [2] reported that the MRR increases with higher such process parameters as applied voltage, tool feed rate, electrolyte concentration, and electrolyte flow rate. A higher machining current in the inter-electrode gap results from an increase in voltage and electrolyte concentration. When the gap between the tool and workpiece is reduced, the tool feed rate increases leading to a higher current density.

Senthilkumar et al. [3] studied the electrochemical machining performance of Al-10 wt % SiC composites. The composites were prepared by the stir casting technique. They revealed that at low voltage applied in ECM, a high SR and a low MRR resulted. But an increased electrolyte flow rate resulted in the acceleration of the chemical reactions, accordingly increasing the MRR. When the applied voltage exceeds a certain limit and the electrolyte flow rate is constant, then more heat is produced that subsequently deteriorates the surface of the machined workpiece.

Hihara et al. [4] used ECM for machining Al-SiC composites using calomel as the tool material and aqueous NaNO₃ as the electrolyte solution. During the anodic dissolution, the matrix material was removed, whereas the inert SiC reinforced particles were removed by the electrolyte flow. The reduction in applied voltage and tool feed rate caused a high SR due to unsteady and nonhomogeneous anodic dissolution. Moreover, as a result of a high current density caused by a higher tool feed rate and the existence of SiC particles in Al matrix, the pits on the workpiece surface were formed. In this process, hydrogen bubbles were produced, which obstructs the anodic dissolution, which, in turn, leads to the formation of the nodular work surface profile. A high electrolyte flow rate that aids in the removal of the hydrogen bubbles and rotation of the tool at a particular speed, could prevent the nodular work surface profile.

Toptan et al. [5] reported on experimentation of ECM of aluminium reinforced with (2.5, 5.0, and 7.5 wt %) B₄C and studied the MRR. They developed a mathematical model for the MRR and applied ANOVA for the analysis. In that model, the mathematical relationship was established in between the input parameters such as applied voltage, tool feed rate, electrolyte concentration and percentage of reinforcement and the response parameter such as the MRR.

Sankar et al. [6] studied the performance of ECM of AA7075-B₄C composites and optimized the responses of the MRR and SR by the response surface methodology, and then the result was analyzed by ANOVA. NaNO₃ was used as the electrolyte in this process. In that study, they considered current, voltage, and tool feed rate as input parameters. It was observed that such process parameters as voltage and tool feed rate highly influenced the MRR and SR. Therefore, the maximal MRR and the minimal SR was achieved at: 8 V applied voltage, 217 A current, and 0.3 mm/min tool feed rate.

Solaiyappan et al. [7] studied the performance of machining of AA6061 alloy with 10 wt % Al₂O₃ and 5 wt % SiC hybrid composites using straight ECM and that optimized by using hybrid fuzzy-artificial bee colony algorithm. They examined the influences of such process parameters as applied voltage, current, tool feed rate, electrolyte concentration, electrolyte flow rate and interelectrode gap on such performance parameters as the MRR, SR, and ROC.

III. EXPERIMENTAL SETUP

Electro Chemical Micro Machining (ECM) is one of the advanced machining processes where material removal takes place through electrolysis phenomena. It is best suited for materials which are difficult to be machined by mechanical machining process. The process is started in the presence of an electrolyte flow that is circulated with the help of special pump filling the gap between anode (work piece) and cathode (tool). Electrolyte flow is adjusted by flow control valve. The machining is achieved by sinking of tool forming its replica. During the operation sophisticated control panel takes care of any damage to the machine by overload and short circuit protections. After desired time interval hooter gives an indication of completion of the time / process. The small machining area with

given power supply an be machined within 30 minutes to one hour.



Figure 3.1 ECMM Setup Working principle of ECMM

It works according to the principle of electrolysis. When electric pulses are passed between anode and cathode, the electrons cross the gap and material from the work piece dissolved and desired shape of material is obtained. The voltage is changed along with the duty cycle is analyzed. Electrochemical machining works inverse as electroplating process. Metal is removed from anode into electrolyte and convert into slag form by reacting opposite ions available in electrolyte. In ECM, the electrolyte is so chosen that there is no plating on tool and shape of tool remain unchanged. Generally, NaCl into water takes as electrolyte. The tool is connected to negative terminal and work is connected to positive terminal. When the current passes through electrode, reaction occur at anode or work piece and at the cathode or tool.

S.NO	LIST OF COMPONENTS	RANGE	QUANTITY
1.	Servo motor	-	1
2.	DC pump	0.32A, 75W	1
3.	Pulsed rectifier	30V, 2A	1
4.	Reservoir	1.5 Litre	1

Table 3.1 Parts and Description

COMPONENTS OF ECM

Servo motor

A servomotor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity, and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotor



Figure 3.2- Servo Motor

DC Pump

A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps.

Pumps operate by some mechanism (typically reciprocating and rotary) and consume to perform moving the fluid. Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power come in many sizes, from microscopic for use in medical applications to large industrial pumps.



Figure 3.3- DC Pump

Pulsed rectifier

The device which operates at above 30V is called an electrical device and the device which operates with less than 30V is called electronic voltage. Even though the electronic devices like transistors are used to amplify the analog signals, they eventually need DC voltage biasing to perform that task. Likewise, so many electronic devices operate on only DC which cannot sustain any voltage changes.



Figure 3.4- Pulsed Rectifier

Reservoir Tank

Reservoir is fixed on the base of the experimental set up. It contains the electrolyte and it holds the workpiece table. The capacity of the tank is to carry up to 1.5 liter of electrolyte.



Figure 3.5- Reservoir Tank

3.3 ECM MACHINE PARAMETERS 3.3.1 Tool Feed Rate

In ECM procedure gap around 0.01 to 0.07 mm is maintained between the tool and work piece. The electrical resistance is small for small gap between the tool and work and maximum current and therefore maximum material will be removed. Depending on how quickly the metal has to be removed, tool is fed towards work.

Material Removal Rate

Electrolysis is the basis of material evacuation. Faraday proposed two laws for this, initial one is "the chemical change

created by an electric current, which is the measure of any material dissolved or deposited, is directly proportional to amount of current supplied". Second is "The amount of different constituents dissolved by the same amount of electricity are proportional to their chemical equivalent weights ". MRR is a function of feed rate. A steady spacing between the tool and the work is in this manner established. The real advantages of the metal removal rate procedure are that they don't bring about certain undesirable surface impacts which emerged in traditional machining processes. The main advantages are that they are stress free machining, burr free surfaces, reduced tool wear and cancellation of thermal damage to the work-piece. These methodologies have no impact on mechanical properties, for example, yield strength, ultimate strength, hardness, ductility etc.

Overcut

ECM can deliver surface finish of $0.45 \mu\text{m}$ by turning of tool or work. Any imperfection on tool face produce replica on work piece. Tool surface therefore in this manner be polished. The finish is better in harder material. For ideal surface finish, careful electrode design, maximum feed rate, and surface improving additives in electrolyte are chosen. Low voltage reduces the equilibrium inter electrode gap and result in better surface finish and tolerance control. Low electrolyte concentration results in reduced machining gap and better surface finish. Low electrolytic temperature additionally improves surface finish.

Electrolyte and its concentration

The electrolyte solution is essential for the electrolysis process to work. An electrolyte in ECM performs three basic functions, which are as follows;

- (1) Completing the electrical circuit and allowing the large current to pass.
- (2) Sustaining the required electrochemical reactions.
- (3) Takes away the heat generated and the sludge.

Electrical conductivity of the electrolytes must be high, toxicity and corrosiveness should be low.

Tool design

Any good conductor can be satisfactorily used as tool material because there is negligible tool wear in ECM process. But it must have sufficient strength to withstand the hydrostatic force, brought on by electrolyte when it is discharged at high velocity through the hole in the middle of tool and work. In order to allow electrolyte to pass along the bore in the tool the tool is made hollow for drilling holes. Most commonly used tool material is copper. Some materials like graphite, brass and copper tungsten are used since they have capability of Machining and non-corrosive properties.

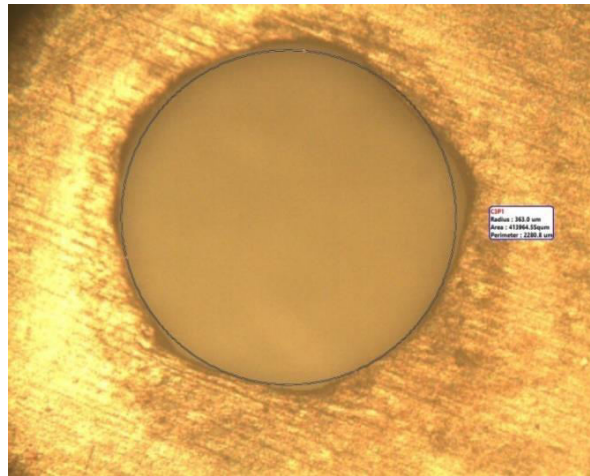
Current

In ECM, current plays a vital role. The material removal rate is directly proportional to the current (i.e. higher is current, more will be material removal rate). Generally, this increase is observed up to a certain value and when current exceeds beyond this level it negatively affects finishing and accuracy of work piece.

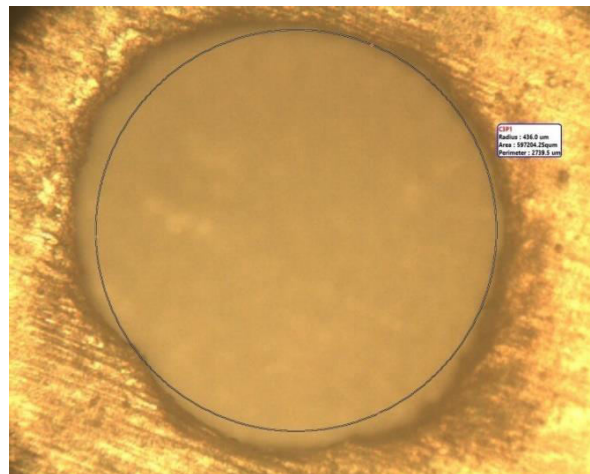
OPTICAL MICROSCOPE IMAGES

The optical microscope, often referred to as the light microscope, is a type of microscope that commonly uses visible light and a system of lenses to magnify images of small objects.

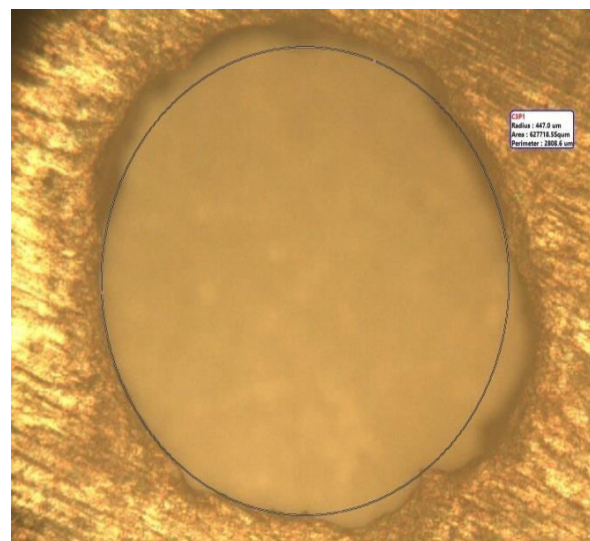
The microscope has a digital camera and is attached to a computer image analysis covers a range of techniques to gather quantitative analysis or measurements from images using sophisticated software. It is also used to calculate the front and back hole diameter. It is helpful to determine the material removal rate and overcut.



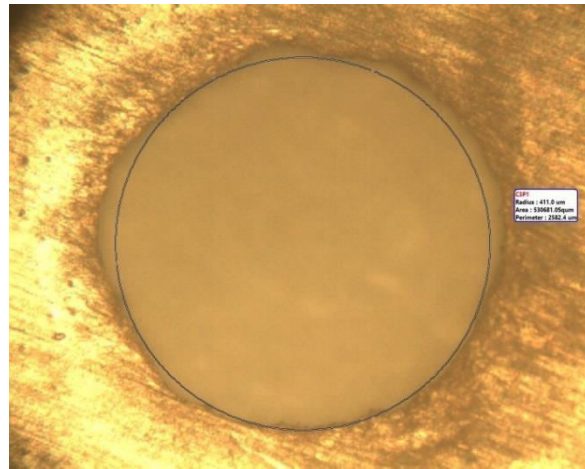
HOLE NO. 11(Using non-heat-treated tool)



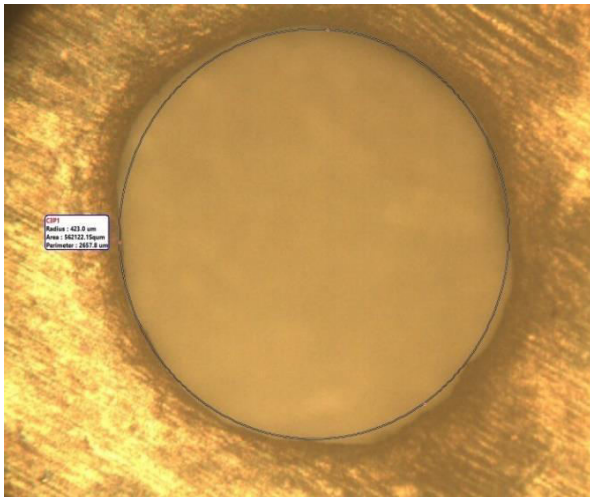
HOLE NO. 18 (Using heat treated tool)



HOLE NO.4(Using non heat treated tool)



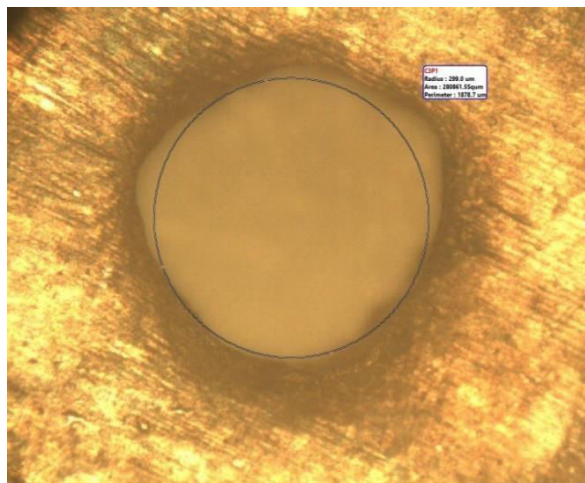
HOLE NO.19(Using heat treated tool)



HOLE NO.22(Using non heat treated tool)



Figure 7.1- Field Emission Scanning Electron Microscope (FESEM)



HOLE NO.30(Using heat treated tool)

FIELD EMISSION SCANNING ELECTRON MICROSCOPE IMAGES

Field emission scanning electron microscopy (FESEM) provides topographical and elemental information at magnifications of 10x to 300,000x, with virtually unlimited depth of field. Compared with conventional scanning electron microscopy (SEM), field emission SEM (FESEM) produces clearer, less electrostatically distorted images with spatial resolution down to 1 1/2 nano meters – three to six times better.

7.1 Principle of Operation

A field-emission cathode in the electron gun of a scanning electron microscope provides narrower probing beams at low as well as high electron energy, resulting in both improved spatial resolution and minimized sample charging and damage.

PROBLEM IDENTIFICATION

Aluminium metal matrix composites (AMMCs) are widely used in the applications of industries such as aerospace, automobile, defense, etc., because of certain significant properties like high strength-to-weight ratio, high stiffness, and high hardness, low wear rate and low coefficient of thermal expansion. Generally, AMMCs are reinforced with some ceramic abrasive particles, which leads to abrasive action during machining. When machining of AMMCs is done with conventional techniques, then high tool wear is reported resulting in the decline of the surface integrity of the material. Machinability of composites is reduced while performing the traditional machine operations such as turning, milling, threading, etc. because those are hard-to-machine materials. In the traditional method, heat is generated during machining at the interface of tool and chip, which influences the surface integrity of the workpiece. Machining cost also increases in the conventional machine to process hard particles reinforced AMMCs. Many researchers reported the machining of metal matrix composites by unconventional machining processes. Laser beam machining and electrical discharge machining (EDM) provide more sub-surface damage to the workpiece than electrochemical machining (ECM). Among the unconventional techniques, ECM is the most significant one that could be employed for machining hard or difficult to cut materials. In this process, metal is removed from the electrically conductive workpiece by controlled dissolution. Here, tool and workpiece are considered as cathode and anode, respectively; both are separated by an electrolyte solution. It is mainly used for the manufacturing of the complex shape components for automotive, aerospace, defence, medical and electronics industries such as engine castings, non-circular holes, bearing cages, forging dies and moulds, turbine blades, artillery projectiles, and surgical implants, etc.. Besides, there are some important merits of ECM such as no stress, no burrs, longer tool life, damage-free machined surface.

IV. METHODOLOGY

DESIGN OF EXPERIMENT & TAGUCHI APPROACH

Taguchi's Approach to Parameter Design Taguchi's approach to parameter design provides the design engineer with a systematic and efficient method for Determining near optimum design parameters for performance and cost. The objective is to select the best combination of control parameters so that the product or process is most robust with respect to noise factors. A brief overview of Taguchi's approach for parameter design.

1. Determine the Quality Characteristic and to be optimized the first step in the Taguchi method is to determine the quality characteristic to be optimized. The quality characteristic is a parameter whose variation has a critical effect on product quality. It is the output or the response variable to be observed. Examples are weight, cost, corrosion, target thickness, strength of a structure, and electromagnetic radiation.
2. Identify the Noise Factors and Test Conditions to identify the noise factors to produce a negative impact on system performance and quality. Noise factors is a parameter which may either uncontrollable or are too expensive to control. Noise factors consist of variations in deterioration of components with usage,
3. environmental operating conditions and variation in response between products of similar design with the similar input.
4. Identify the Control Parameters and Their Alternative Levels to identify the control parameters thought to have significant effects on the quality characteristic. Control (test) parameters are those design factors that can be set and maintained. The levels (test values) for each test parameter must be chosen at this point. The numbers of levels, with related test values, for each test parameter was defining the experimental region.
5. Design the Matrix Experiment and Define the Data Analysis Procedure A specific study is required to get proper orthogonal arrays for the noise and control. Taguchi gives many standard orthogonal arrays and corresponding

linear graphs for this function. After selecting the appropriate orthogonal arrays, a process to simulate the variation in the quality characteristic due to the noise factors wants to be defined. A general approach is the use of Monte Carlo simulation. However, for an precise estimation of the mean and variance, Monte Carlo simulation requires a huge number of testing conditions which can be expensive and time consuming. As a substitute, Taguchi proposes orthogonal array-based simulation to assess the mean and the variance of a product's response ensuing from variations in noise factors. Using this approach, orthogonal arrays are used to sample the domain of noise factors. The experimental results for each combination of control and noise array experiment are denoted by $Y_{i,j}$

6. Conduct the Matrix Experiment the Taguchi method may be used in any condition wherever there is a controllable process. The controllable process can be a real hardware experiment, computer models or systems of mathematical equations that can be effectively model for the response of many products and processes.
7. Analyze the Data and Determine the Optimum Levels The optimal test parameter pattern within the experiment design must be determined, after the experiments have been conducted. For analysis of the results, the Taguchi method uses a statistical measure of performance called signal to noise (S/N) ratio borrowed from electrical control theory. The S/N ratio produced by Dr. Taguchi is a performance measure to select control levels that most excellent cope with noise. The S/N ratio takes both the mean and the variability into relation.

V. CONCLUSION

The result showed that the machining rate for heat treated tool is 2 times better than the non-heat- treated tool. Field emission scanning electron microscope (FESEM) images show much difference insurface structure for heat treated tool and non-heat- treated tool. The findings provide valuable understandings on heat the tool to improve the performance of EMM systems.

PHOTOGRAPHY





REFERENCES

- [1]. Thanigaivelan R; Arunachalam R.M; Drupka, Pelden. Drilling of micro holes on copper using electrochemical micro machining. The International Journal of Advanced Manufacturing Technology 2012, 61, 1185–1190.
- [2]. S. K. Mukherjee, S. Kumar and P. K. Srivastava effect of Over Voltage on Material Removal Rate during Electrochemical Machining Journal of Science and Engineering, Vol. 8, No 1, pp. 23-28 (2005).
- [3]. H. Hocheng, Y.H. Sun, S.C. Lin, P.S. Kao A material removal analysis of electrochemical machining using flat-end cathode Journal of Materials Processing Technology 140 (2003) 264– 268.
- [4]. Bhattacharyya, B.Malapati, M.Munda, J.Sarkar, influence of tool vibration on machining performance in electrochemical micro-machining of copper. International Journal of Machine Tools and Manufacture 2007, 47, 335–342.
- [5]. Thanigaivelan R, Arunachalam R.M, Drupka, Pelden. Drilling of micro holes on copper using electrochemical micro machining. The International Journal of Advanced Manufacturing Technology 2012, 61, 1185–1190.
- [6]. Chunhua Suna, Di Zhu, Zhiyong Li, LeiWang Application of FEM to tool design for electrochemical machining freeform surface journals of Finite Elements in Analysis and Design 43 (2006) 168 – 172.
- [7]. Mohan Sen., H.S. Shan A review of electrochemical macro- to micro-hole drilling processes International Journal of Machine Tools & Manufacture 45 (2005) 137–152.



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