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Advances in simulation modeling and analysis of curvilinear electro chemical machining process

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ABSTRACT

The complex contour machining is often encountered in the electrochemical machining, in this circumstance it is difficult to check the machined parameters exactly before it deliver to client. On other hand as it is costly operation and degree of accuracy demanded is very high, one must ensure exact settings of the machining parameters and predicts its perfectness before machining. Certain machining parameters changing over time while machining the contour profiles. It is hard to find exact machining time also. Ultimately the error free machining must be ensured. The new profiles must be studied before machining. All these can be done by means of simulation analysis before actual machining. This paper deals with simulation of electro chemical machining. These paper discuses the boundary condition analysis in electrochemical machining with use of VECM CAD 2.1 and advanced features in analyzing the curvilinear machining is comparatively analyzed and presented. Key parameters were tested effectively and proposed solution outperformed. The proposed methodology responded the key parameters changes as well as any input values changes at any instant of time during the simulation which leads to design the optimal machining conditions.

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1. Preamble

The electro chemical machining would be costlier when it designed for processing dynamically as well as multidimensional and complicated process control requirements. Though the technology advanced well, some of the challenges faced in achieving them exactly as desired. Simulation is a tool to predict the consequences of the effort; it addresses many what if question for understanding the behavior of the process [1–3]. As it is expensive machining as well as costly work material, it must be ensured that what is the capability of machine to achieve the intended geometry. The trial and error method is very difficult; time consuming, exact prediction is rare. Here simulation helps to learn that make know the augmentation requirements, deviations in shape and dimensions with respect to machining speed, varying the machining parameters while machining profile, repeatability requirements for achieving the intended profile on the work piece. Some other issues are reported in the literature that machining time analysis with shape change in the contour machining. Shape of the tool/electrode and its geometrical profile requirements must be predicted to achieve the intended job [4]. Prediction of final shape of work piece and its deviation while altering the parameters or conditions of machining. In addition to that, investigations must be carried out economically to determine the innovative methods which amplify accuracy of machining. The advanced machining technology like numerical control machining, machining parameters optimization and process structure optimization, Control of machining by means of computer or microcontroller. The profound study requires to understand the physical phenomena of machining and its relation with parameters of machining and their intrinsic limitations etc. support to fix the parameters for machining to make decision on the quality of machining that is accuracy requirements, possible economy in machining etc. and avoiding the critical state. The critical state is one at which machining is sporadic, electrodes are spoiled or some other state of interruption. Hence it was insisted that the study on constraints is very important [5–7].

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2. Profiling

The profile modeling is often referred as designation, which includes defining the allocation of the physical–chemical state of affairs taking place in the electro chemical machining area, (The physical–chemical state of affairs of ECM includes the decision on volume fraction of gas phase, the flow rate of electrolyte in to the system, distribution of static pressure and temperature), to designate the surface contour (profile) of the electrode with respect to time, the task of defining the gap between the anode and cathode (Inter-electrode gap). The appropriate definition by determination of these constrains helps to narrow down the simulation for the desired profile especially curvilinear or curved surfaces.

3. Simulation modeling

Simulation modeling is process of converting the mathematical expression to perform the numerical analysis with respect to time so that the one can simulate the activities like flow of electrolyte across the gap between anode and cathode, moving the tool to machining complicated contours, demonstrating the tool vibration in the desired directions (usually axial direction) in real time effects. The numerical simulation of triggering of tool with vibration electrode for curvilinear surfaces was investigated [8–11]. The equation for evaluating machined surface presented [2,3,8,9] and detailed algorithm developed [12–14].

4. The BCA

Unlike flat surface machining the curvilinear surface machining is complicated in ECM as it requires variable gaps between the anode and cathode and maintains the flow of electrolyte on it requires different flow route. Such complexity was already reported by proof in empirical studies and theoretical studies [15–18]. The numerical simulation offers solution to the complexity by means of boundary conditions analysis (BCA). Here the boundary conditions meant that critical state. In this analysis the factors are investigated at which values it reached boundary conditions. Such range of variation of parameters meant its ability or capability. Some of the critical parameters of electro chemical machining were investigated and suggested the way of altering them are explained here below.

4.1. Positive flow velocity of electrolyte

In curvilinear profile machining, the flow velocity of electrolyte could be alter by slow down feed to maintain the height when it tends to reduce. The tool holds some time by temporary stoppage when it height variation not found while machining. Based on the work profile requirements tool electrode may be pulled back. Hence required gap can be altered while machining entire profile.

4.2. Negative flow velocity of electrolyte

In curvilinear profile machining, at some circumstance the negative flow velocity of electrolyte may be happen due to some work profile nature. In those circumstance either low frequency or high frequency or both (if necessary) may be stepping down Hence Negative Velocity of electrolyte can be altered while machining entire profile.

4.3. Electrolyte temperature

In curvilinear profile machining, Electrolyte temperature could be alter by slow down feed of tool electrode, when inter electrode gap tends to reduce. The tool holds sometime by temporary stoppage when it height variation not found while machining. Based on the work profile requirements tool electrode may be pulled back. Hence required gap can be altered while machining entire profile.

4.4. Height of inter-electrode gap

In curvilinear profile machining, the inter electrode gap or height of the tool from the work could be alter by slow down feed to maintain the height when it tends to reduce. The tool holds sometime by temporary stoppage when it height variation not found while machining. Based on the work profile requirements tool may be retracted. Hence required gap can be altered while machining entire profile.

4.5. Gas phase volume concentration

In curvilinear profile machining gas phase volume concentration could be alter by slow down feed of tool electrode, when inter electrode gap tends to reduce. The tool holds some time by temporary stoppage when it height variation not found while machining. Based on the work profile requirements tool electrode may be pulled back. Hence required gap can be altered while machining entire profile.

It is comprehensively understood that the only five kinds of action requires maintaining the five key parameters. For better understanding it is depicted diagrammatically in Fig. 1. Within the span time of simulation the alteration activity to be carried out as and when required for the respective case.

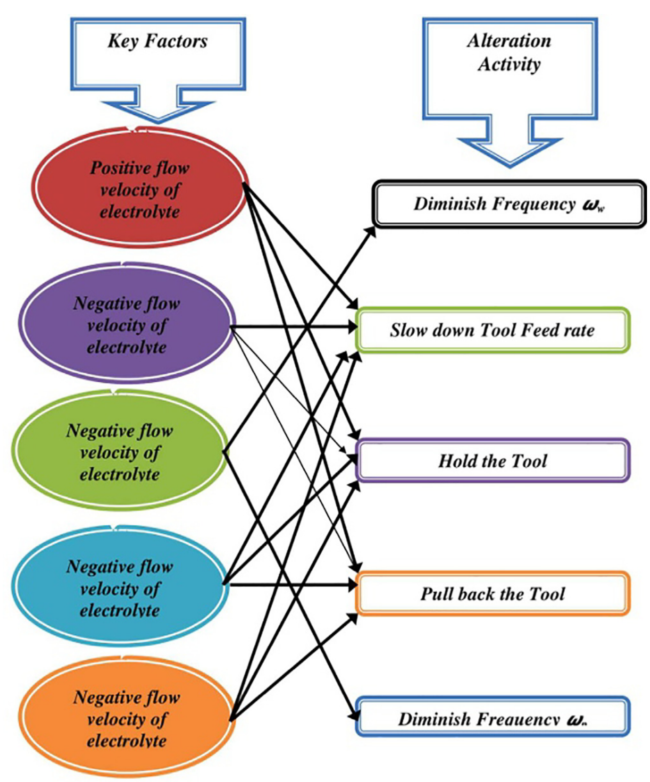

Fig. 1. Key parameters and alteration activities.

4.6. Adoptive control

The adoptive control helps to execute the numerical codes (commands) which generated for electro chemical machining of curvilinear surface. The adoptive control performs the necessary alteration to perform the electro chemical machining on work material to generate the curvilinear surface. The adoptive control accepts the input code process them and delivers control codes (Fig. 2).

5. Conventional programming

The general applicable programming procedure depicted with help of flow chart [11]. In which some the terms to be explained that the tool electrode, Number of curves, work piece, machine control parameters, Machining status indicator, current time, minimum gap, intermediate time of storing simulation events or step of simulation time, Total simulation time, maximal temperature, time of saving work piece's shape and Machining parameters values, electrolyte velocity maximum and minimum are represented in the flow as TE, K, WP, MCP, MCI, t, Dmin, Δts, T, Tmax. Ts, Vxmax, Vxmin respectively. The programming codes are briefly explained. The feed rate (mm per min) written as 'NXXX F0 56′, here XXX indicates the three digit line index number. Similarly the Temporary stop 500 ms to be coding as 'NXXX G4 500′, the parameters update as 'NXXX G1 Y1.75′, longitudinal vibrations as 'NXXX S50′ transverse vibrations as 'N110 SP32′, machining end-point as 'NXXX G1 Y0.52′ move to the starting point as 'N060 G1 Y0′ for oscillation phase shift by 90 degrees is 'N050 SA 90′ and initial - feed rate mm/min as 'N150 F0.7′.

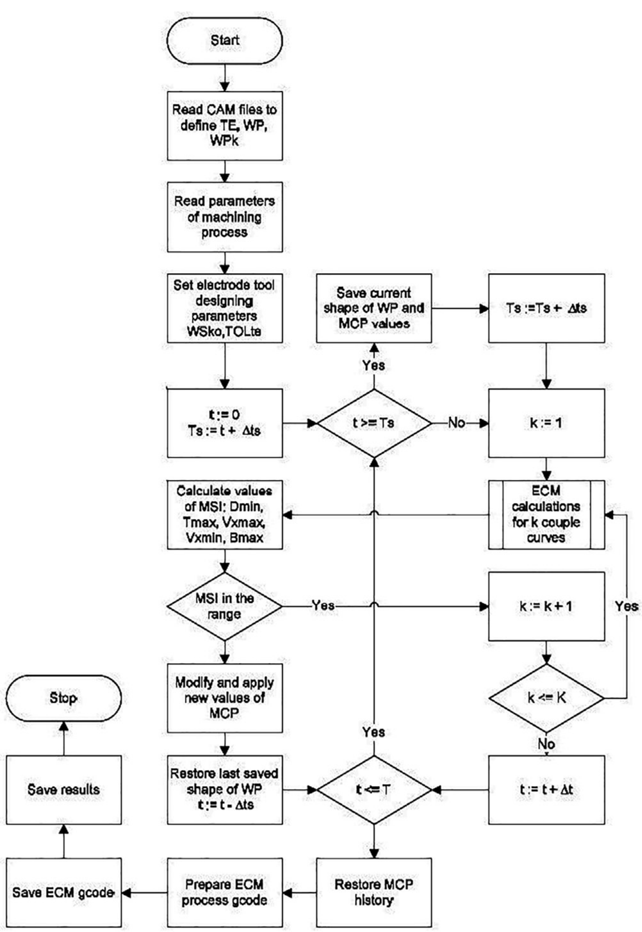

Fig. 2. Structure of BCA programming.

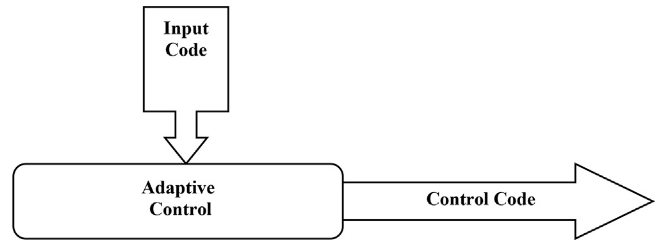

Fig. 3. Schematic diagram of Process Control.

6. Proposed programming

The proposed machining programming used VECM CAD 2.1 software. The module has facilities the enter only numerical values, uploading coded files and some select options, through which the machining environment, variables, boundary conditions, process parameters, level of interaction, etc. can be defined by the user. In this system the typographical error, manual mistakes, omits can be minimized. The training to the investigator also made easy.

Hence the BCA is performed in the proposed system that the adoptive control unit interact with parameters interaction that is Key parameters and alteration activities and based on the input codes delivers control codes to perform the intended curvilinear electro chemical machining (Refer Fig. 3).

In the proposed software module has choice to define the shared inter-relationships between parameters and system reaction can be made, with a given level of interaction. In addition to that it enable that code generating to control hallowing, saving the selected settings, loading new files, editing or modifying options at any instant of machining simulation.

7. Conclusion

The computer aided modelling and simulation of electro chemical machining operation always yielded economy in time as well as money and also added flexibility. The same was illustrated in this paper. It simplifies the complicated analysis hence it is applicable to analysis the complicated like electro-chemical Machining of hole. The BCA of electrochemical machining operations under the constraint of complicated tool surface in particularly curvilinear motion is discussed the discussed about the code changing at any instant of time obtained. The proposed BCA has the potentials to improve the accuracy of machining and its stability not only in simple contours but also complicated tool geometry. The five key factors examined for boundary conditions occurrence. The analytical and the numerical integration of complex systems of partial differential equations employed for acquiring solution in the proposed method, which permits to design complex numerical algorithms for simulating and analyzing simultaneously, in an electro chemical machining of curvilinear geometries while editing or revising the controlled machining parameters or factor of electro chemical machining at any instant of time.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] Saravanan Rathinasamy, R. Raju, Int. J. Adv. Manuf. Tech., 49 (1–4) (2010) 213–225.
[2] Fritz Klocke, Lukas Heidemanns, Markus Zeis, Andreas Klink, Procedia CIRP 68 (2018) 499–504.
[3] Matthias Hackert-Oschätzchen, Raphael Paul, Michael Kowalick, André Martin, Andreas Schubert, Procedia CIRP 31 (2015) 197–202.
[4] S. Skoczypiec, K. Furyk, A. Ruszaj, Procedia CIRP 6 (2013) 444–449.
[5] D. Deconinck, J. Deconinck, Procedia CIRP 6 (2013) 475–478.
[6] Dengyong Wang, Zengwei Zhu, Hongrui Wang, Di Zhu, Chin. J. Aeronaut. 29–2 (2016) 534–541.
[7] Badal Dev Roy, R. Saravanan, Int. J. Curr. Trends Sci. Technol. 4–12 (2017) 6369–6375.
[8] Marius Purcar, Leslie Bortels, Bart Van den Bossche, Johan Deconinck, J. Mater. Process. Technol. 149 (2004) 472–478.
[9] L. Dąbrowski, T. Paczkowski, Russ. J. Electrochem. 41 (1) (2005) 91–98.
[10] M. Purcar, L. Bortels, B.v.d. Bossche, J. Deconinck, J. Mater. Processing Tech. 149 (2004) 472–478.
[11] A. Godwin Antony, V. Vijayan, S. Saravanan, S. Baskar, M. Loganathan, Analysis of wear behaviour of aluminium composite with silicon carbide and titanium reinforcement, international journal of mechanical, Eng. Technol. 9 (2018) 681–691.
[12] V. Vijayan, S. Saravanan, A. Godwin Antony, M. Loganathan, S. Baskar, Heat transfer enhancement in mini compact heat exchanger by using alumina nanofluid, Int. J. Mech. Eng. Tech. (IJMET) 10 (01) (2019) 564–570.
[13] S. Saravanan, A. Godwin Antony, V. Vijayan, M. Loganathan, S. Baskar, Synthesis of SiO2 nano particles by using sol-gel route, Int. J. Mech. Eng. Technol. 1 (2019) 785–790.
[14] S. Dinesh, A. Godwin Antony, K. Rajaguru, V. Vijayan, Experimental investigation and optimization of material removal rate and surface roughness in centerless grinding of magnesium alloy using grey relational analysis, Mech. Mech. Eng. 21 (2017) 17–28.
[15] S. Dinesh, K. Rajaguru, V. Vijayan, A. Godwin Antony, Investigation and prediction of material removal rate and surface roughness in CNC turning of EN24 alloy steel, Mech. Mech. Eng. 20 (2016) 451–466.
[16] S. Baskar, V. Vijayan, S. Saravanan, A.V. Balan, A. Godwin Antony, Effect of Al2O3, aluminium alloy and fly ash for making engine component, Int. J. Mech. Eng. Tech. (IJMET) 9 (12) (2018) 91–96.
[17] S. Baskar, V. Vijayan, I.J. Isaac Premkumar, et al., Design and material characteristics of hybrid electric vehicle, Mater. Today: Proc., Received 26 April 2020, Accepted 11 May 2020, Available online 18 June 2020.
[18] B. Suresh Kumar, V. Vijayan, N. Baskar, Burr dimension analysis on various materials for convenantionally and CNC drilled holes, Mech. Mech. Eng. 20 (2016) 347–354.