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INVESTIGATION OF EDM PARAMETERS BY USING GRA & TAGUCHI METHODS ON COMMERCIAL ALUMINIUM (1050A)

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ABSTRACT

Optimization is one of the techniques used in manufacturing sectors to arrive the best manufacturing conditions, which is an essential need for industries towards manufacturing of quality products at lower cost. This Project aims to investigate the optimal set of process parameters such as current, pulse ON time and pulse OFF time, spark gap voltage in Electrical Discharge Machining (EDM) process to identify the variations in five performance characteristics such as rate of material removal rate, electrode wear rate on tool, taper angle, machining time and overcut value on the work material for machining Aluminium 1050A using copper electrode. Based on the experiments conducted on L25 orthogonal array by Taguchi method, analysis has been carried out using Gray Relational Analysis. Response tables and graphs were used to find the optimal levels of parameters in EDM process. The confirmation experiments were carried out to validate the optimal results. Thus the machining parameters for EDM were optimized for achieving the combined objectives of higher rate of material removal, lower wear rate on tool on the work material considered in this work. The obtained results show that the Gray relational Analysis is being effective technique to optimize the machining parameters for EDM process.

KEY WORDS-Metal removal rate, Electrode wear ratio, Pulse ON time, Pulse OFF time, Gray relation analysis.

I.INTRODUCTION

In a machining process, in order to improve machining efficiency, reduce the machining cost, and improve the quality of machined parts, it is necessary to select the most appropriate machining conditions. The higher material removal rate and the lowered the electrode wear ratio, over cut, taper angle and machining time preferred in machining processes.

The cost per machined part is a performance measure for a number of manufacturers. The need to minimize the manufacturing cost has led to higher demand for increased manufacturing productivity. Cutting fluids are significant part of machine operating cost. Cutting fluids are used in machining to reduce the detrimental effects of heat and friction on both tool and work piece. Efforts to reduce the use of cutting fluids in metal cutting are being made from the viewpoint of cost, ecological and human health . Such drawbacks can be reduced or eliminated by performing the machining operations with higher material removal rate and the lower electrode wear ratio, over cut, taper angle and machining time in machining processes. consists of atomizing a very small quantity of lubricant in an airflow directed toward the cutting zone. Above all the factors leads to economical benefits by the way of saving manufacturing costs and work piece/tool/machine cleaning cycle time.

Material removal rate, electrode wear ratio, over cut, taper angle and machining time all the factors can be calculated by using EDM(ELECTRICAL DISCHARGE MACHINING), and analysis has been done by using taguchi methods and gray relation analysis and rank order has given for the best optimum result.

II. PRINCIPLE AND WORKING OF EDM (ELECTRICAL DISCHARGE MACHINE)

Electrical Discharge Machining (EDM) is a controlled metal-removal process that is used to remove metal by means of electric spark erosion. In this process an electric spark is used as the cutting tool to cut (erode) the work piece to produce the finished part to the desired shape. The metal-removal process is performed by applying a pulsating (ON/OFF) electrical charge of high-frequency current through the electrode to the work piece. This removes (erodes) very tiny pieces of metal from the work piece at a controlled rate.

2.1 EDM PROCESS:

The electrical discharge machine (EDM) removes work piece by an electrical spark erosion process. Common methods of evaluating machining performance in EDM operation are based on the following performance characteristic: MRR and EWR.

Basically, this characteristics' are correlated with the machining parameters such as work piece polarity, pulse on time, and pulse off time, current spark gap voltage, and discharges current and dielectric fluid. Proper selection of the machining parameters can obtain higher material removal rate, and lower electrode wear ratio. Machining takes place by the discharge pulse from the cathode to the anode. Usually, the polarity is set, so that the work piece acts as the anode and the tool electrode acts as the cathode, in order to obtain a higher material removal rate. The discharge pulse gap is relatively small, thus the accuracy of components or parts manufactured by EDM is very high. EDM is accomplished with a system comprising two major components: a machine tool and power supply. The machine tool holds a shaped electrode, which advances into the work material and produces a high frequency series of electrical spark discharges. The sparks are generated by a pulse generator, between the tool electrode and the work material, submerged in a liquid dielectric, leading to metal removal from the work material by thermal erosion or vaporization. The spark erosion of the work material makes use of electrical energy, converting them into thermal energy through a series of repetitive electrical discharges between the tool electrode and the work material electrode. The thermal energy generates a channel of plasma between the two electrodes, at a temperature ranging from 8000 to 12,000 ◦C, and as high as 20,000◦C. When the pulsed DC supply ~20,000-30,000 Hz, is switched off, Melting and vaporization of the work material dominates the material removal process in EDM, leaving tiny craters on the surface of the work material. EDM has no contact and no cutting force process, and therefore does not makes direct contact between tool electrode and the work material. The rate of material removal is dependent upon the following factors: amount of pulsed current in each discharge, frequency of the discharge, electrode material, work material and dielectric flushing condition. Diameter overcut (dimensional accuracy) becomes important when close tolerance components are required to be produced for space application and also in tools, dies and moulds for press work, plastic moulding and die casting.

2.2 MATERIAL

Recently, the application of aluminum and its alloys in automotive and aerospace industries is widely growing. In machining of aluminum and its alloys, since they have highly adhesive characteristics compared with steels, more effective lubrication is often necessary, though they are not so hard. In this investigation have used commercial aluminium 1050A which has excellent corrosion resitance, high ductility and highly reflective finish, moderate strength.

IV. EXPERIMENTAL SETUP

In this project, electrode wear ratio (EWR) is important, Electrode tool wear is also a parameter to measure the ease of machining in the EDM processes, because the total energy of discharge pulses is not only used to machine the work piece, but also degrades the tool electrode. Another important parameter machining time, over cut, taper angle. This five characteristic, has a major influence and resulting the machining performance. The experimental studies were performed on a electrical discharge machining as seen in Fig.2 The experiments were conducted under different settings pulse ON, pulse OFF, spark gap voltage, peak current, servo.

Fig.1 Setting of work piece in EDM

Fig.2 EDM Control parameters

INPUT PARAMETERS AND THEIR LEVELS:

Parameters	Units	Level 1	Level 2	Level 3	Level 4	Level 5
Pulse on time	µs	3	4	5	6	7
pulse off time	µs	5	6	7	8	9
Spark gap set	V	180	210	240	270	300
peak current	A	3	6	9	12	15
Servo	%	30	60	90	120	150

Table 1.Machining Settings

4.1 EXPERIMENT PROCEDURE:

A specially designed experimental procedure is required to evaluate the effects of machining parameters on performance characteristics. Conventional experimental design methods are too complex and difficult to use. Additionally, large number of experiments has to be carried out when number of machining parameters increases. Normally, the full-factorial design would require 5^5 experimental runs in this study. However, the effort and experimental cost for such a design could be prohibitive and unrealistic. We used Taguchi method, a powerful tool for parameter design of performance characteristics, to determine optimal machining parameters for maximum MRR, minimum EWR, overcut, taper angle, machining time in EDM. Taguchi method proposes to acquire the characteristic data by using orthogonal arrays and to analyze the performance measure from the data to decide the optimal process parameters. The method uses a special design of orthogonal arrays to study the entire parameter space with small number of experiments only. Five machining parameters were used as control factors (Table 1). According to the Taguchi quality design concept, a L_{25} orthogonal arrays table with 25 rows (corresponding to the number of experiments) was chosen for the experiments these Taguchi experiments were performed on EDM. And corresponding Output parameters were listed for the further calculations of MRR, EWR, over cut,taper angle, machining time by using following formula.

EXPERIMENTAL RUNS & RESPONSES

Ex no	A Pulse on time	B Pulse off time	C Spark gap voltage	D Peak current	E Servo	MRR mm^3/min	EWR mm^3/min	OC mm	TA deg	MT min
1	1	1	1	1	1	74.48766	0.65363322	0.155	26.6	17.19
2	1	2	2	2	2	70.96225	1.555747623	0.145	24.42	6.5
3	1	3	3	3	3	513.1458	7.900280899	0.125	24.1	1.28
4	1	4	4	4	4	609.4656	13.80338459	0.115	4.47	0.732
5	1	5	5	5	5	718.885	10.94482277	0.145	23.88	0.513
6	2	1	2	3	4	43.63809	1.381905541	0.125	20.89	10.57
7	2	2	3	4	5	75.15075	1.096190737	0.15	25.24	8.2
8	2	3	4	5	1	48.16171	2.803597231	0.15	28.89	5.21
9	2	4	5	1	2	51.85416	0.982736594	0.145	24.42	17.15
10	2	5	1	2	3	56.72481	0.534197546	0.2	17.57	6.31
11	3	1	3	5	2	519.1069	10.47419539	0.2	21.46	1.18
12	3	2	4	1	3	10.4551	0.187265918	0.225	25.40	60
13	3	3	5	2	4	12.95887	0.197295084	0.135	11.46	34.17
14	3	4	1	3	5	17.70775	0.280828669	0.125	20.89	40.01
15	3	5	2	4	1	27.12089	0.388619284	0.155	26.6	23.13
16	4	1	4	2	5	17.82559	0.256431078	0.225	17.66	26.29
17	4	2	5	3	1	201.8406	2.16596724	0.225	21.33	4.15
18	4	3	1	4	2	268.3663	4.441088955	0.145	24.42	2.53
19	4	4	2	5	3	84.02473	0.715665927	0.115	4.47	6.28
20	4	5	3	1	4	39.69362	0.716236179	0.125	20.89	12.55
21	5	1	5	4	3	21.37233	0.460725989	0.167	23.13	19.51
22	5	2	1	5	4	433.921	1.733943682	0.02735	6.69	3.24
23	5	3	2	1	5	123.4826	1.539171926	0.3188	23.88	5.11
24	5	4	3	2	1	20.4644	0.441587753	0.007177	17.57	22.9
25	5	5	4	3	2	50.15584	0.218173885	0.009301	9.99	10.3

Table 2 Calculations of MRR, EWR, OC, TA, MT

V. GRAY RELATIONAL ANALYSIS

Grey relation analysis is an effective means of analyzing the relationship between sequences with less data and can analyze many factors that can overcome the disadvantages of statistical method. In a complex multivariate system, the relationship among various factors is usually unclear. Such systems are often called as "gray" implying poor, incomplete, and uncertain information. Gray relational analysis is an impacting measurement method in gray system theory that analyzes uncertain relations between one main factor and all the other factors in a given system. When experiments are ambiguous or when the experimental method cannot be carried out exactly, gray analysis helps to compensate for the shortcomings Data preprocessing in gray relational analysis. This analysis can be used to represent the grade of correlation between two sequences so that the distance of two factors can be measured discretely. Grey relation analysis is an effective means of analyzing the relationship between sequences with less data and can analyze many factors that can overcome the disadvantages of statistical method.

5.1 DATA PREPROCESSING:

Data pre-processing is a process of transferring the original sequence to a comparable sequence. For this purpose the experimental results are normalized in the range between zero and one. The normalization can be done form three different approaches. For data preprocessing in the gray relational analysis process, " the higher MRR, lower

EWR,OC,TA, machining time " are the indication of better performance in milling process. Then, it has a characteristic of the "higher is better" if the target value of original sequence is infinite. The original sequence can be normalized as following :

$$x_i^*(\mathrm{k})=\frac{x_i^o(k)-min x_i^o(k)}{max x_i^o(k)-min x_i^o(k)} \quad (1)$$

where i=1,…,m; k=1,…,n. m is the number of experimental data items and n is the number of parameters. $x_i^o(k)$ denotes the original sequence, $x_i^*(k)$ denotes the sequence after the data preprocessing, max $x_i^o(k)$ denotes the largest value of $x_i^{(o)}(k)$, min $x_i^o(k)$ denotes the smallest value of $x_i^o(k)$, and x^o is the desired value.

When the "lower is better" is a characteristic of the original sequence, the original sequence should be normalized as following :

$$x_i^*(\mathrm{k})=\frac{max x_i^o(k)-x_i^o(k)}{max x_i^o(k)-min x_i^o(k)} \quad (2)$$

In gray relational analysis, the measure of the relevancy between two systems or two sequences is defined as the gray relational grade. When only one sequence, $x_0(k)$, is available as the reference sequence and all other sequences serve as comparison sequences, it is called a local gray relation measurement. After data preprocessing is carried out, the gray relation coefficient $\xi_i(k)$ for the k^{th} performance characteristics in the i^{th} experiment can be expressed as following:

$$\xi_i(k)=\frac{\Delta_{min}+\varsigma\Delta_{max}}{\Delta_{0i}(k)+\varsigma\Delta_{max}} \quad (3)$$

where, Δ_{0i} is the deviation sequence of the reference sequence and the comparability sequence.

$$\Delta_{oi}(k) = \| x_o^*(k)- x_i^*(k)\| \quad (4)$$

$$\Delta_{min} = \min_{\forall j\epsilon i} \min_{\forall k} \| x_0^*(k) - x_j^*(k) \| \quad (5)$$

$$\Delta_{max} = \min_{\forall j\epsilon i} \min_{\forall k} \| x_0^*(k) - x_j^*(k) \| \quad (6)$$

Ex no	COMPARABILITY SEQUENCE					DEVIATION SEQUENCE				
	MRR	EWR	OC	TA	MT	MRR	EWR	OC	TA	MT
1	0.09039	0.965749	0.52564	0.09378	0.71966	0.909613	0.034251	0.47436	0.90622	0.28034
2	0.08541	0.899495	0.55773	0.18305	0.89936	0.91459	0.100505	0.44227	0.81695	0.10064
3	0.70958	0.433538	0.62191	0.19615	0.98711	0.290416	0.566462	0.37809	0.80385	0.01289
4	0.84555	0	0.654	0.97952	0.99631	0.154453	1	0.346	0.02048	0.00369
5	1	0.20994	0.55773	0.20516	1	0	0.79006	0.44227	0.79484	0
6	0.04684	0.912263	0.62191	0.3276	0.83094	0.95316	0.087737	0.37809	0.6724	0.16906
7	0.09132	0.933246	0.54168	0.14947	0.87078	0.908677	0.066754	0.45832	0.85053	0.12922
8	0.05323	0.80785	0.54168	0	0.92105	0.946774	0.19215	0.45832	1	0.07895
9	0.05844	0.941579	0.55773	0.18305	0.72033	0.941562	0.058421	0.44227	0.81695	0.27967
10	0.06531	0.974521	0.38123	0.46355	0.90255	0.934687	0.025479	0.61877	0.53645	0.09745
11	0.718	0.244504	0.38123	0.30426	0.98879	0.282001	0.755496	0.61877	0.69574	0.01121
12	0	1	0.301	0.14287	0	1	0	0.699	0.85713	1
13	0.00353	0.999263	0.58982	0.71376	0.43421	0.996466	0.000737	0.41018	0.28624	0.56579
14	0.01024	0.993129	0.62191	0.3276	0.33604	0.989762	0.006871	0.37809	0.6724	0.66396

15	0.02352	0.985212	0.52564	0.09378	0.6198	0.976475	0.014788	0.47436	0.90622	0.3802
16	0.0104	0.99492	0.301	0.45987	0.56668	0.989596	0.00508	0.699	0.54013	0.43332
17	0.27015	0.854679	0.301	0.30958	0.93887	0.729846	0.145321	0.699	0.69042	0.06113
18	0.36406	0.687589	0.55773	0.18305	0.9661	0.63594	0.312411	0.44227	0.81695	0.0339
19	0.10385	0.961193	0.654	1	0.90306	0.896151	0.038807	0.346	0	0.09694
20	0.04127	0.961151	0.62191	0.3276	0.79766	0.958728	0.038849	0.37809	0.6724	0.20234
21	0.01541	0.979916	0.48713	0.23587	0.68066	0.98459	0.020084	0.51287	0.76413	0.31934
22	0.59775	0.886408	0.93526	0.90909	0.95416	0.402247	0.113592	0.06474	0.09091	0.04584
23	0.15955	0.900713	0	0.20516	0.92273	0.840453	0.099287	1	0.79484	0.07727
24	0.01413	0.981322	1	0.46355	0.62367	0.985871	0.018678	0	0.53645	0.37633
25	0.05604	0.99773	0.99319	0.77396	0.83548	0.94396	0.00227	0.00681	0.22604	0.16452

Reference sequence for MRR, EWR,OC,TA,MT=1.0000

Table 3 Comparability sequence and Deviation sequence after Data pre processing

x_0*(k) denotes the reference sequence and x_i*(k) denotes the comparability sequence. ζ is distinguishing or identification coefficient: ζ ∈ [0,1] (the value may be adjusted based on the actual system requirements). A value of ζ is the smaller and the distinguished ability is the larger. ζ=0.5 is generally used.

After the gray relational coefficient is derived, it is usual to take the average value of the gray relational coefficients as the gray relational grade. The gray relational grade is defined as following:

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n}\zeta_i\,(k) \quad (7)$$

However, in a real engineering system, the importance of various factors to the system varies. In the real condition of unequal weight being carried by the various factors, the gray relational grade in Eq. 7 was extended and defined as follows:

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n}\zeta_i\,(k)w_k \quad \sum_{k=1}^{n}w_k = 1 \quad (8)$$

where w_k denotes the normalized weight of factor k.

The gray relational grade γ_i represents the level of correlation between the reference sequence and the comparability sequence. The value of gray relational grade is equal to 1 if the two sequences are identically coincidence.

Table 4. Gray relation coefficient and coefficient grade

Ex run	A	B	C	D	E	GRAY RELATION COEFFICIENT					GRAY RELATION GRADE	ORDER
						MRR	EWR	OC	TA	MT		
1	1	1	1	1	1	0.354707	0.935889	0.513155	0.355562	0.640744	0.56001142	17
2	1	2	2	2	2	0.353459	0.832633	0.530631	0.379664	0.832446	0.58576677	12
3	1	3	3	3	3	0.632578	0.46884	0.569415	0.38348	0.974871	0.6058367	8
4	1	4	4	4	4	0.763996	0.333333	0.591013	0.960661	0.992681	0.72833694	4
5	1	5	5	5	5	1	0.387579	0.530631	0.386148	1	0.6608715	6
6	2	1	2	3	4	0.344078	0.85072	0.569415	0.426476	0.747319	0.5876016	11
7	2	2	3	4	5	0.354943	0.882218	0.521746	0.370224	0.794638	0.58475392	13
8	2	3	4	5	1	0.345596	0.722387	0.521746	0.333333	0.863627	0.55733804	21

9	2	4	5	1	2	0.346846	0.895381	0.530631	0.379664	0.641296	0.5587637	19
10	2	5	1	2	3	0.348508	0.951512	0.446919	0.482418	0.836897	0.61325081	7
11	3	1	3	5	2	0.639385	0.398249	0.446919	0.418151	0.978076	0.57615607	16
12	3	2	4	1	3	0.333333	1	0.417016	0.368426	0.333333	0.49042166	25
13	3	3	5	2	4	0.334121	0.998529	0.549339	0.635938	0.469138	0.59741276	9
14	3	4	1	3	5	0.335624	0.986443	0.569415	0.426476	0.429569	0.54950527	23
15	3	5	2	4	1	0.338644	0.971274	0.513155	0.355562	0.568054	0.54933787	24
16	4	1	4	2	5	0.335661	0.989943	0.417016	0.480709	0.535723	0.5518103	22
17	4	2	5	3	1	0.406555	0.774809	0.417016	0.420021	0.891052	0.58189041	14
18	4	3	1	4	2	0.440164	0.615452	0.530631	0.379664	0.936502	0.58048266	15
19	4	4	2	5	3	0.358127	0.927976	0.591013	1	0.837604	0.74294412	3
20	4	5	3	1	4	0.342764	0.927904	0.569415	0.426476	0.711903	0.59569241	10
21	5	1	5	4	3	0.336793	0.961384	0.493645	0.39553	0.610245	0.55951939	18
22	5	2	1	5	4	0.554172	0.814874	0.885371	0.846154	0.916024	0.80331891	1
23	5	3	2	1	5	0.373008	0.834325	0.333333	0.386148	0.866142	0.55859114	20
24	5	4	3	2	1	0.336503	0.963989	1	0.482418	0.570561	0.67069414	5
25	5	5	4	3	2	0.34627	0.995481	0.986555	0.688663	0.752424	0.75387847	2

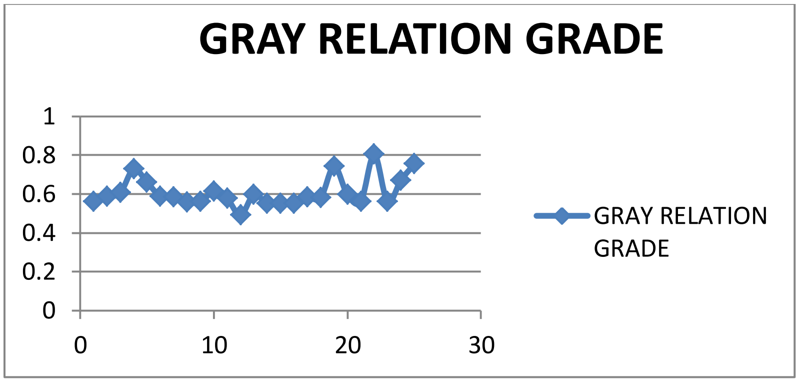

Fig.4 Gray relation grade for the multi EDM parameters

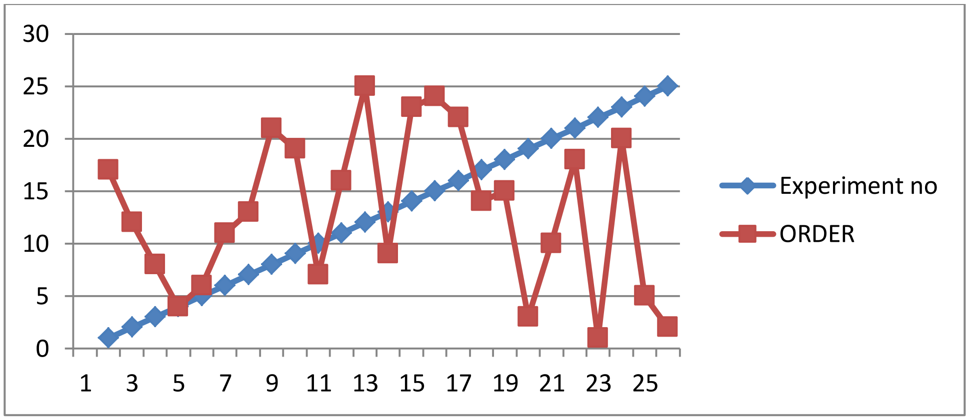

Fig.5 Effect of EDM parameter for rank order

RESULT AND DISCUSSION

In these operations, maximum MRR, minimum EWR, minimum OC, minimum TA, minimum MT are an indication of better performance. For data pre -processing in the gray relational analysis process, EWR, OC, TA, MT were taken as the "lower is better" and and the MRR were taken as the "higher is better" respectively. Let the results of 25 experiments be the comparability sequences and deviation sequences $x_i^o(k)$, i=1–25, k=1 after data pre-processing using Eqs.5 and 6 are listed in Table 3 and denoted as $x_o*(k)$ and $x_i*(k)$ are reference sequences and comparability sequences, respectively. Table 4 the same calculation method performed for i=1–25 and the results of gray relation coefficient for i=1–25.The distinguishing coefficient ζ can be substituted into Eq. 7 to produce the grey relational coefficient. The grey relational coefficients and grade values for each experiment of the L25 orthogonal array were calculated by applying the Eqs. 8–10 (Table 4). According to the performed experimental design, it is clearly observed from that the input parameters' setting of run 22 has the highest grey relational grade. Therefore, run 22 is the optimal machining parameters' setting for minimum EWR, OC, TA, MT and maximum MRR simultaneously (i.e., the best multi performance characteristics) among the 25runs.

CONCLUSION

The Grey relational analysis based on an orthogonal array of the Taguchi methods was a way of optimizing the process parameters in drilling for Al 1050A alloy. The analytical results summarized as follows:

1. The maximum MRR and the Minimum Electrode wear rate, over cut, taper angle, machining time were selected as the quality targets.
2. From the response table of the average gray relational grade, the largest value of gray relational grade for the EDM parameters was obtained at A5, B2, C1, D5, E4.
3. i.e. pulse on time(7μs), pulse off time(6μs),spark gap(180v),peak current(15A),servo(150%)
4. It is the recommended levels of the controllable parameters for the process of drilling as the minimization of Electrode wear rate, over cut, taper angle, machining time and maximization of MRR.

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