Optimization of Machining Process Parameters to Reduce Rejection Rate using Taguchi Model

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Abstract

For carrying out the experiments to examine the practical effects of various parameters on the expected value of system output characteristics, quality improvement techniques, especially Taguchi procedure, are used. We have discussed the ways to optimize the machine to reduce the rejection rate in manufacturing units. Along with the experiments and study of data, the papers discuss advantage and disadvantage of using Taguchi Methodology in optimizing machining process. The Taguchi technique is applied to the rejection management of versatile hose assemblies in various industries (especially in automobile) in this article. A correlation between the influences of process variables at the end product is attempted. Experiments are conducted to verify the findings obtained through the application of Taguchi method in the automotive working industries, and the most relevant parameters influencing product existence are identified. The desired amounts of process conditions are determined to produce goods with the best quality characteristics. The influence of chosen process parameters and their scales is investigated using an orthogonal series, the signal to noise (S/N) ratio, and (ANOVA)measurement of variance.

1. Experiment

When model parameter variance exists, suboptimal values for fine PID tuning are used.(excessive volume) They also calculated how much each factor contributed to the overall variance as well as the variability of the mistake, the expected cost savings from PID service under ideal conditions was calculated. They have used a true PID controller to perform validation checks. The effect of welding parameters on stainless steel tensile shear intensity was investigated by Esme (2009).

RSW (resistance spot welding) is a method of welding. Experiments were made in order to learn more about the topic. There are several variations in electrode temperatures, electrode diameters, welding currents, and welding times. The impact of welding parameters on tensile shear strength was also investigated. The use of estimation of variation was used to arrive at this conclusion (ANOVA). Welding parameters that are suitable to evaluate the combination, the signal-to-noise ratio (S/N) was used. They're very nice and the tensile shear strength may be improved, according to confirmation studies. Utilising the Taguchi method The results of the experiments backed up the theory. The Taguchi process's suitability for increasing welding productivity and optimising the welding parameters for the resistance spot welding operation.

Short fibre obtained from agricultural resources is used to reinforce the structure. The ideal length for a short storey fibre, which could only move weight and maintain its stability through exercise, had been repurposed.The research was carried out using a systematic modelling approach as well as an empirical model. The effect of parameter settings on the wear degree (weight loss). Fibers with a length of 7-8 hours are recommended.

The composites' minimum wear is measured in millimetres.The application and usefulness theory of the Taguchi system were explored by Badkar et al. (2010). In order to improve the laser process parameters that are used in the laser hardening of metals, to manufacture commercially pure titanium, a continuous-wave Nd:YAG laser is used. They took advantage of ANOVA, signal-to-noise ratio, and additive models are some of the techniques used to analyse data. The model was used to try and figure out what the best laser mixture quantities were parameters for the hardening step of the transformation. As a result of the optimization results, increased scanning speed (SS) and centred point position (FP) are combined in this technique.

Increase in the laser power (LP) in combination with an increment in the defocused pulse with a negative focal length, Lowering the degree is an essential parameter for laser hardening in order to minimise HD at the same time.The formability of perforated sheets is determined by their thickness, according to Elangovan & Narayanan (2010). On the substance's chemical structure, the parameters used to create it, the perforation dimensions, and so on the length of the ligaments. The shaping boundary for a 1mm perforated Al 8011 sheet is depicted in that diagram. The width, as well as the results of the perforation diameters and other factors, had been calculated.

The relationship between the developing maximal strains and the widths of the ligaments was studied. According to Wazed et al. (2010), individual and cumulative effects of common components and machines were quantified in this study. Manufacturing is hampered by bottlenecks and unpredictably changing conditions. They used machines to accomplish their goals. Breakdown and continuity volatility both lead to uncertainty. The mode of dissemination was studied by the scientists. Indicators of performance include

i. finished product throughput,
ii. overall cycle time, and
iii. ongoing system testing to enable a variety of experimental scenarios. These are good simulations, created based on a real-world scenario involving a Malaysian business.

A batch size of 12 in a bottleneck, two common ingredients, and four basics cum simple machines were determined to be essential.In the face of doubt, determine what the system's best outcomes are the prime concern, their research helps by deciding the best batch size to use at bottlenecks. Uncertainty, shared features, and capacity limits are all factors to consider.

A radio receiver was designed which needed a low bit rate of error in ground-to-aircraft communication for data transmission. Firstly, creating a collection of trials that solve questions linearly will be too costly. In contrast, the job of computer simulation was time-consuming and costly to test a certain standard. But how is it possible to speed up production and to assure reliability? In a different project, a firm had brought a high speed copying machine to the market only to find that the feeder jammed about 10 times more than expected. For many weeks, it used the customary way to evaluate the dependability of a single current design idea. The Robust Design methodology has all helped to save manufacturing time and costs by two or more factors. In all these scenarios In general, engineering decisions taken during a device or technique creation may be split into two categories: Implementation of prior mutual experience and understanding without mistake is developed, often to increase product quality/reliability, efficiency and cost. New design knowledge (Jangra et al., 2011). Although CAD/CAE technologies help to apply past information, the robust design method, which amplifies engineering skill, greatly improves the efficiency of the creation of new information. Robust Architecture enables a company to swiftly realise the full technological value of its design ideas and to continue to increase profits.

The removal of changes is well recognised as an incentive for increased efficiency and production. There are a number of approaches to mitigate variability, each of which has its own place in the manufacturing process (Jang et al., 1997). By tackling the reduction of heterogeneity at a certain stage in the product development cycle, downstream mistakes may be avoided. The Six Sigma technology has led to considerable cost reductions by detecting and correcting problems in industrial or white-collar operations (Ho et al., 2004). The approach to robustness involves improving the product and designing manufacturing methods to prevent difficulties.

The manufacturer of a differential op-amplifier in coin phones faced a problem of inadéquate offset voltage because of manufacturing uncertainties. High offset voltage, especially for phones placed distant from the main office, generated poor speech quality. So, what’s the greatest strategy to reduce the expenses and problems in the field? Some approaches are available. Repay customers for any harm that they may have experienced.Screen out circuits with a broad offset voltage at the end of the assembly line.Assembly line process management can allow you to attain better tolerances. To the degree the operation of the circuit, especially its production variance, will no longer be affected by the source, the nominal values of important circuit paramaters should change (Jangra et al. 2011). Robustness technology is the fourth solution. When you choose the approach 1 to 4, the upstream distribution cycle continues to improve cost management effectiveness. The situation must be dealt with sooner rather than later in this respect. The robustness method provides the main method for strategies to reduce the systemic exposure of designs to distinct decreases of variability. It may be used to improve product design and production process design.

Over the past five years, several big organisations have invested heavily in the Six Sigma approach for waste reduction in production and operation. These actions have had an important impact on and, as a consequence, on the cost structure of those enterprises. We were all able to make full use of the usual Six

Sigma method. This and other similar findings of prominent companies encourage them to use the Design for Six Sigma banner to better manufacture their products.

The Six Sigma technique focuses on two things: 1) improvement of production efficiency, allowing for fast, affordable production of revolutionary technologies, and 2) value-based management (Sommer et al. 2012). For engineering efficiency the usage of the Robust Design methodology is crucial. Dr. Genichi Taguchi, who discovered this technology following the conclusion of WWII, developed it throughout the last five decades. Many companies throughout the globe have saved 100 million dollars using the technology in a range of areas, including autos, xerography, telecommunications, optics, applications, etc. (Gokler et al. 2000).

The Taguchi approach is employed while rotating to discover the optimal cuts for surface roughness. The orthogonal array, signal-to-noise ratio, and analysis of variance were employed to evaluate the performance characteristics of TiN coated tools in turning operations of AISI 1030 steel bars. Taking into account surface roughness, the modification of three working conditions: insert radius, feed rate and cutting force. The efficacy of this strategy is shown by experimental data (Sommer et al. 2012).

Typical numerical simulation models are constructed using the finite element methodology to resolve pressure, flow, and temperature ranges. With the increasing reliance on numerical modelling, commercial simulation programmes have evolved into commonplace tools for improving mould design and process control in injection moulding. This is particularly true when manufacturing elaborate or precise components, and when numerical simulation may be used to make virtual adjustments to component and mould designs. It is true that saving time and money for frequent modifications in component and mould designs is difficult. However, given the swarm of simulation assessments that lack a systematic experimental design, considerable efforts are still required to determine optimal values. The Taguchi methodology and the integrated method to numerical coupling are therefore beneficial, since the former can model situations that are difficult to implement in practise, while the latter provides the advantages of shorter simulation trials and analysis of the findings to optimise them (Zalnezhad et al. 2016).

Artificial neural networks (ANN) are a mathematical or computer model that attempts to replicate the structure and/or function of biological brain systems. The design has many levels, with one or more buried between the input and output layers. In the layers, there are processing units known as neurons. To reach their output to the following layer, all neurons in the previous layer will receive the complete input and process it via an activation process. An artificial neural network (ANN) must be trained by methodically analysing sets of input values and outputs.

During the learning stage, it adjusts its structure based on external or internal network input. Its structure is altered as a result of this. A well-trained neural network system may convert nonlinear statistical data modelling into a simple black-box structure that represents intricate data input-output relationships.Genetic Algorithm is a stochastic, evolutionary biological search approach that improves solutions via heredity, mutation, selection, and cross-purpose searching, among other things. The solution begins with a symbolic string, referred to as a randomly produced or selected chromosome, and each symbol in the chromosome is referred to as a 'allleal-value' gene. Throughout the whole chromosomal group, there is a population. The chromosomes develop across numerous iterations or generations, assessing the fitness of each individual chromosome in the population and stochastically picking multiple chromosomes from the current population, which then undergo cross-sections and mutations to create a new generation.

Crossovers involve splitting two chromosomes and then combining the other half of each chromosome into one half. Mutation is the process of reducing the best chromosome to a single bite while eliminating the other chromosome. The method has been iterated to the maximum number of generations, or an optimal or nearly optimal parameter configuration has been found. When the process has run for a certain number of generations, however, the best answer may or may not have been discovered (Sommer et al. 2012). In order to improve product efficiency and operations, industries need a testing procedure. Chemical industrial systems continue to strive for the same goal. Experiment design is the first stage in streamlining procedures to increase efficiency in this case. This requires precise experiment preparation and execution, as well as a thorough assessment of the outcomes. Dr. Taguchi has thoroughly researched and recognised his technique as a solution to these issues. As a result, engineers and scientists based on the Taguchi paradigm found DOE to be a considerably more appealing technique. Since the emergence of standard concept modelling approaches for industrial applications or processes, these traditional approaches have typically been afflicted with faults and limitations.

Taguchi array architecture, also known as orthogonal array architecture, is a higher-level experimental design. The Taguchi process is a well-known DOE method that has shown its capacity to produce high-quality goods at a low cost. In most manufacturing systems or processes, the Taguchi technique has been merged with other distinct ways of computing, and it has also demonstrated a beneficial effect in process optimization in industrial chemical processes. An estimate approach was provided for a multi-cut Wire-EDM process (Kravets et al., 1992). Both the frequency of the removal of metals and the volume of machining were affected by surface resilience, although they were difficult to forecast. In addition, no discussion was held regarding how to choose the appropriate machining parameters for each process, such as period of pulsation and pulse off, etc. In Wire-EDM, Scott et al. (1991) employed a factory modelling tool to determine the optimal combination of control settings. 729 experiments led in the discovery of 32 parameters of machining which resulted in better metal removal rate and surface roughness.

The WEDM approach employed by Tarng et al. (1995) to choose the optimum machining parameter using a virtual annealing (SA) algorithm, however it needed so much experimentation with this methodology. The optimal machining settings to achieve the specified surface roughness could not be calculated nevertheless. Based on the design of the Taguchi Quality experiment, regression analysis, viable route and variance analysis A method to assess optimum parameter settings was presented by Liao et al. (1997) who addressed the use of Grey theory to optimise EDM multi-response methods. The ideal processing settings to achieve the necessary surface roughness could nevertheless not be established. As a consequence of the high cost and time consumption of performance assessment and many machining factors, as well as the challenge of building genuine mathemic models, the decision about the ideal machining larameters remains problematic. The objective of this research is to explain how Gray relational and statistical analysis may be used in order to determine the major characteristics that influence wire-EDM machining efficiency. In addition, the ideal combination of machining settings is available for optimal machining speed and minimum surface roughness using Gray relational analysis. In order to establish the appropriate machining settings for the desired surfatile roughness and the optimal metal removal rates, the Gray relational analysis is also available.

1.1 Internal Manufacturing Rejection

It is India's forerunner in the production of vehicle tubing. In 1969, the company was founded. It sells its products to companies including New Holland, Suzuki, and DCM Toyota. Where as companies like Nissan and Mahindra are two of the most well-known automobile manufacturers in the world. It also manufactures hoses and valves for automobiles and attracted a large number of applicants. The business established a joint venture with TRI in 2005. It has earned ISO-9000 certification. Pipe assemblies, hose assemblies, and tube assemblies are all available. Hoses with several layers, stainer assemblies, moulded parts, and pipes for a wide range of application (Tyagi etal. 2020). Automobile parts are distributed all over the world. Flexible hose assembly pipes are often used in automobiles for transporting oil and air.

The key issue is that the crimping joint on the flexible hose has failed. Internal rejections data from April 2009 to March 2010 were taken into account, this industry Internal rejection specifics and the process of interpretation are the subject of study. Crimping Leakage and Banjo Face have been cited as the main causes for rejection (Kechagias et al. 2020). Banjo Fault, Breach, Pipe Breach, Brazing Fault, Crimping Fault, Crack (Nut, Bolt, Screw, Bolt) Hose Puncture, Improper Fitment, and Nipple and Pipe are only a few examples. The following table summarises the various options. Defects in the Flexible Hose Assembly that led to its rejection are mentioned below.

Table 4 Rejection rate across different aspects of manufacturing

Reasons	**Rejection in Nos.**	**Rejection in %**
Crimping's Leakage	1599	59.17
Banjo Face Leakage	588	21.72
Pipe Leakage	15	05.45
Banjo Fault	135	04.95
Brazing Leakage	126	04.63
Crimping Fault	65	02.35
Crack (Nut, Nipple & Pipe)	22	00.78
Hose Puncture	14	00.49
Improper Fitment	13	00.45
TOTAL	2710	100

The biggest fault in the Flexible Hose Assembly is leakage in the Crimping Joint, as revealed by the in-house exclusion dependent on defects.Flexible Hose Assembly was dismissed in around 59 percent of the cases (Kechagias et al., 2020) The cause-and-effect relationship is the relationship between cause and effect. In order to evaluate the possible causes for the crimping leakage flaw, a diagram is made.

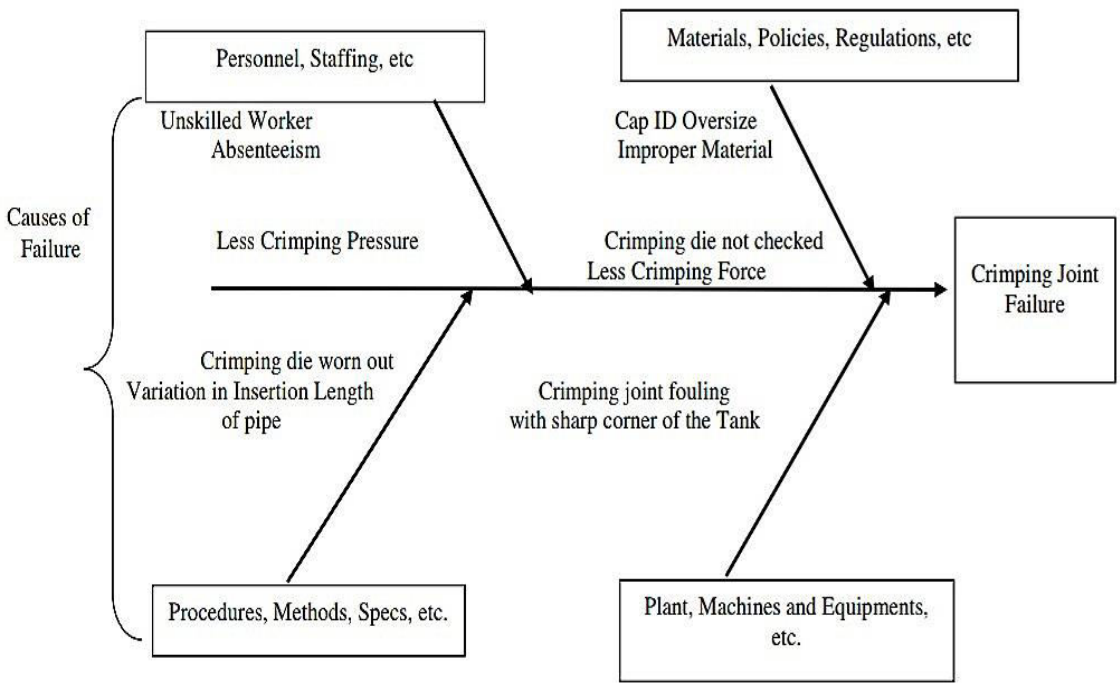

Figure 6 Structure of the failure

Observations

The possible reasons of the Crimping leakage problem are described and illustrated in the reason and effect diagram below.

1. Lessening of the crimping tension
2. Reduce the time it takes to put a pipe hose or a tube into a seal.
3. A cap with an excessively large inner diameter
4. Unpredictable crimping depth
5. Unsuitable Materials
6. There is no crimping technique used.

1.2 Taguchi Method Applicability

To assess the right solution for rejection purposes, the Taguchi method is used. Hose Pipe Assembly Crimping Leakage is caused by three major flaws: insufficient crimping depth, hose length variation, and cap inner diameter variation (oversize). The following table describes the function parameters and their corresponding ranges, as seen below.

Table 5 Process parameter

Parameter designation	Process parameter	Range
A	Less Crimping Depth (in mm)	0.36-0.4
B	Hose Length Variation (in mm)	17-21
C	Cap I.D. Oversize (in mm)	15.4-15

The number of parameters and their interactions that are of interest, as well as the number of degrees correlated with the parameters that are of interest, are also important factors when selecting an orthogonal sequence. As seen in the above table, the L8 orthogonal array is taken into account in this case study. Two important considerations must be made when selecting an orthogonal series:

1. The overall amount of factors that ought to be considered, as well as the relations between them.
2. The number of thresholds applicable to the appropriate requirements.

As seen in the table below, the L8 orthogonal array is taken into account in this case study**.**

Table 6 L8 Orthogonal array

Trial serial no.	A	B	A*B	C	A*C	B*C	A*B*C
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1

5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

Following the characteristics and relationships for a given volume/list of the specified orthogonal map, the variables at different levels for each trial are dispersed. (Nas et al. Europe 2020) The studies are duplicated twice using a single randomization replication method with the same sample set; for each testing scenario the crimping leakage deficiencies are determined. The lightweight shaft mounting was intended to resist the tough circumstances of the test.

Table 7 Experimental L8 Array

Trial no	**Less Crimping Depth (mm)**	**Hose Length Variation (mm)**	**Cap I.D. Oversize (mm)**
1	0.35	18	15.5
2	0.35	18	16.0
3	0.35	22	15.5
4	0.35	22	16.0
5	0.4	18	15.5
6	0.4	18	16.0
7	0.4	22	15.5
8	0.4	22	16.0

The crimping leakage faults are reduced by greater quality. For every one of the eight trials, the lower the better S/N ratios are calculated and sample calculations are also calculated.

Lower is better

$$S/N_{LB}ratio = -10log[\sum \frac{y_i^2}{n}]$$

For optimising the performance characteristic, as per the following equation, the following values of the S/N ratio are determined.

$$S/N_i = -10log[\frac{1}{N_i}\sum_{u=1}^{N_i} \frac{y_i^2}{N_i}]$$

The S/N ratio is calculated as in the following equation in order to maximise the performance characteristic.

$$S/N_i = -10log[\frac{1}{N_i}\sum_{u=1}^{N_i} \frac{1}{y_i^2}]$$

where n is the number of observations and y_i are the different experimental values for various trials in the experiment.

1.2.1 Mean Casting Defects & S/N Ratios

The following picture depicts a graphical depiction of the mean response for each parameter, which relates to the average value of the performance characteristics (crimping leakage faults and S/N ratios). The CI was computed to have a consistency level of 90%. To be compared to the confirmatory test, the ideal result must be anticipated. To assess the optimum predicted approach, the confidence interval was calculated using the following equation.

$$CI = (F(\alpha, 1, v_e)V_e(\frac{1}{n_{eff}} + \frac{1}{r}))^{\frac{1}{2}}$$

The guessed optimum range of reduction for 90%confidence interval is:2.936192 < µ < 2.938071

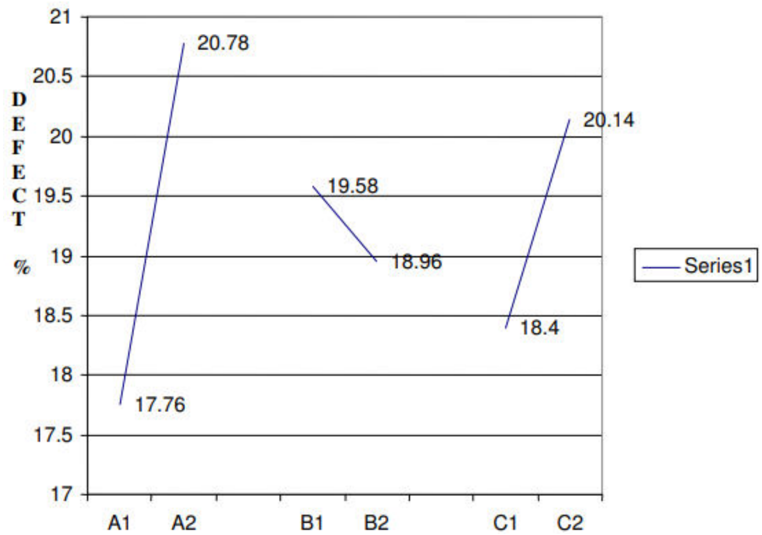

Figure 7 Average value of crimping defect on different levels

1.3 Results & Discussion

The Taguchi method is also used to determine the ideal answer for rejection reasons. Three major defects: reduced crimping depth, variable in tube lengths and capID are examined when it comes to crimping the tube assembly leaking. Once parameters and parameter interactions for a certain column of the specified orthogonal array have been allocated, factors are allocated to each test at various levels. Twice the tests are run using a single randomization procedure for almost the same range of constraints. In each test settings, the crimping leakage flaws are evaluated. The flexible tube assembly is carried out from the test circumstances.

Source	Sum of Square	Degree of Freedom	Variance	F-ratio	Result	% Contribution
A	35.6	1	35.6	18.4596	Significant	52.58%
B	1.54	1	1.54	.75239		.021%
AB	.75	1	.75	.40126		.011%
C	11.90	1	11.9	5.93977	Significant	17.49%
AC	.30	1	.3	.14241		.004%
BC	2.05	1	2.03	1.13177		.029%
ABC	.33	1	.33	.16873		.004%

Error(e)	16.75	8	~2			
Total	69.22	15				

ANOVA table is produced to discover the most significant aspect influencing the casting blowholes. The table below summarizes the findings of the ANOVA leakage crimping fault in the hose assembly. The participation percentage is the proportion of overall variance identified in the study attributable to the examined factors. This input measures the degree of influence of each processing parameters and helps to choose among different variables the most significant component in the procedure. The impact % for the cosnidized process parameter for the research is presented in table below. The participation % for each process parameter is provided in the table above. Out from chart it is obvious that the Phase 1, followed by the limit switch position, the physical stress and the phase-2, contribute a maximum of 33 percent. It is again obvious from the foregoing talks that Phase-1 velocity is perhaps the most important process parameter for determining the metallic refusal rate.

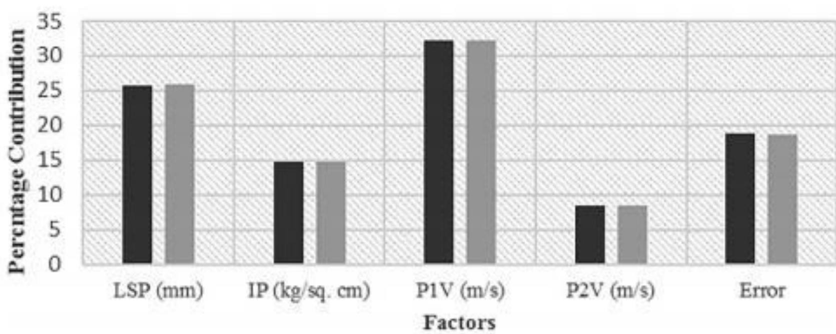

Figure 8 Factor v. Percentage Contribution

From the ANOVA table it is obvious that the lower crimping depth and the average thickness of the cap significantly influence the elastic crank shaft. The optimal amounts for these components may be achieved by considering the mean value of the components. Different tests in the flexible hose construction products have been performed for this test case. The table below shows ANOVA, along with the interpretation technique, the mean values of each factor and optimal values of each parameter. The chart illustrates that the two most critical factors influence both the mean and also the variance of crimping leakage faults and also illustrates the ideal settings of each factors to decrease the crimping leakage errors.

Table 8 Process parameter optimum level with optimum value

Parameter-designation	Process parameter	Optimum level	Optimum value	Percentage contributed
A	Less cimpling depth	1	.36	50.54
C	Cap ID	2	16	17.50

Before using the Taguchi approach, the crimping leakage process variables were random and more challenging to regulate and quality of the product naturally has difficulties with instability. The Taguchi approach produced optimum control parameters leading to greater reliability and stability of the product. The research indicates that the best improvements at the lowest potential cost may be obtained using the Taguchi parameter development model. The optimal amounts of signal factors may also be identified, to minimise the influence of the noise factor on the process parameters. Taguchi model obtains optimum process parameters, i.e. a reduced crimping depths of .36mm and a cap ID of 16mm, which leads to mining leaking faults.

2. Conclusion

The discussion we made, clearly shows how the couple of critical parameters which affect both the mean and variance of crimping leakage like defects, as well as the optimal settings for each parameter that reduce crimping leakage defects and thereby improve the performance of flexible hose assembly at the minimum possible cost. The parameters governing the crimping leakage function were more absurd and tough to handle prior to the introduction of Taguchi's approach, and the resulting product quality suffered from instability. Taguchi's method culminated in improved control factors, resulting in a higher-quality, more durable commodity. Taguchi's method of parameter architecture can be used to achieve the maximum possible performance at the lowest possible cost, according to the research(Sui et al. 2020). Additionally, the optimum signal factor amounts that reduce the effect of noise on the response parameter can be determined. The unit parameters are refined using the Taguchi method, resulting in a lower crimping of depth -0.35 mm and a cap of inner diameter of about 16 mm (Zalnezhad et al. 2016). Crimping leakage errors are reduced as a consequence of this. Furthermore, the validation studies include a thorough understanding of how each component leads to variability in the flexible hose assembly process of manufacturing, allowing for quality enhancement without the need for more investment.

In order to optimise processes and increase product performance, industries need a method for conducting testing. Chemical processing methods are in the same boat. The design of experiments is a crucial first step in improving performance by simplified procedures in order to achieve this (Sui et al. 2020). This involves meticulous test planning and arrangement, as well as accurate data collection. Taguchi put in a lot of time and effort into researching and developing his scheme. As a result, DOE using the Taguchi model has proven to be a better attractive forum for working engineers and scientists. Traditional experimental modelling methods have also had drawbacks and shortcomings when they have been applied to industrial implementations or architectures. Furthermore, the Taguchi series, also known as orthogonal array architecture, adds another dimension to traditional experimental design (Tyagi et al. 2020). Taguchi is a well-known DOE approach that has been shown to deliver high-quality products for a low price.

The Taguchi methodology was paired with other analytical approaches in the majority of manufacturing structures or methods studied by researchers and scientists, and it is also demonstrating excellent results in the optimization of industrial chemical processes. Ensure that the product performs effectively in loud conditions is a critical and fundamental aspect of Taguchi's approach; this leads to the product's long-term viability. Taguchi's method is easy to put into practise; it takes no effort and greatly alters practises. Through applying Taguchi's strategy, manufacturing firms will enhance their processes very fast & quite efficiently (Sommer et al. 2012). The Taguchi approach, which uses orthogonal arrays to optimise process parameters and reduce the no. of tests, is demonstrating outstanding performance in industrial processes.

The Taguchi approach pushes them to greater levels by making procedures more valued, safe and better quality. The involvement of specific quality parameters is the decisive factor to regulate the product design. A regularly used statistical therapy, ANOVA, has been used to interpret the data of the orthogonal array study in product development and to identify the contribution of each element of quality. The general patterns of the elements which influence the product or process may be discovered by analysing the primary impact of each of elements. Data clearly shows that the main factors impact the mean and variance of leakage failures and also the ideal adjustments of every parameter to minimise the leakage failure of crimping, and thus enrich the effectiveness of adaptable shaft assembly at a minimal price. Before using Taguchi's approach, the characteristics of the crimping leakage process were more random and hard to regulate and the product quality had, of course, issues of instability. The Taguchi approach produced optimum control parameters resulting in greater quality and stability of the product. The research shows that quality improvements at the least potential cost may be obtained using the Taguchi parameter development strategy. The ideal amounts of singular features at which the influence of the noise factor on the response parameter is minimised may also be determined. Optimum process parameters reduce crimping leakage faults. The confirmatory studies also provide a clear picture of each factor's contribution to the change in the production process of flexible shaft assembly and improved efficiency without extra expenditure.

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