

Analyzing The Effect of Aspect Ratios on Optimal Parametric Settings Using Taguchi, Taguchi-Pareto, and Taguchi-ABC method: A Case Study in Turning Operations for The Inconel X750 Alloy

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ABSTRACT

The aspect-based Taguchi optimization approaches have been newly accepted as important routes to optimizing the turning experimental parameters. Unfortunately, due to its embryonic development, scholars have left unexplained the effects of introducing the aspect ratios on the optimal parametric setting. To correct this deficiency, this article proposes an approach to evaluating the effects of introducing aspect ratios in turning experiments, combined with direct factors, on the optimal parametric settings. To correct this deficiency, the purpose of this article is to highlight that a standard universal evaluation method is absent in optimization analysis using the Taguchi method; it proposes an approach to evaluating the effects of introducing aspect ratios in turning experiments, in combination with direct factors, on the optimal parametric settings. Using A novel method of establishing the influence of introducing aspect ratios on the optimal parametric settings is suggested using literature review, and the examination method may be a solid basis for optimal parametric setting evaluations in future undertakings of turning operational evaluations. The Inconel X750 alloy is considered in turning operations, and experimental data from the literature are used to illustrate the method. This article finds that quantifiable differences in the mean values of optimal parametric settings exist for the turning operation of Inconel X750 alloy. The study's originality is its attention to the aspect ratio analysis regarding the optimal parametric setting in a wide range of values. This article aims to initiate discussions for a universal agreement on how the influence of introducing the aspect ratios in the factor-level combination framework of the Taguchi method may be constituted. The utility of this research effort is to enhance resource distribution planning for turning operations.

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1. INTRODUCTION

Turning is a pervasive machining operation conducted on the lathe machine (Prashanthakumar et al., 2021; Zaman et al., 2021). It uses a sharp cutting tool to remove excess material from the outer diameter of a rotating workpiece (Pervaiz et al., 2013). However, the workpiece rotates with a high-speed cutting tool, which is usually fixed and is thrust into the workpiece to reduce its diameter to the desired dimension (Ishfaq et al., 2019). Over the years, accumulated heat and frictional effects

have confronted the turning process engineers, and operations and biodegradable cutting fluids have been suggested (Das et al., 2020) Prashanthakumar et al., 2021; Singh et al., 2022). Fortunately, the use of biodegradable cutting fluids in machining has been found to help promote heat transfer, reducing the effects of friction and reducing production time (Singh et al., 2022). However, with more intense studies, nanofluids have been discovered (Prashanthakumar et al., 2021; Singh et al., 2022). But the concept of nanofluids involves combining

cutting fluids and nanoparticles in machining to improve the overall process (Tosun et al., 2016). However, to further improve knowledge on cutting fluids, research dictates that the addition of nanoparticles in cutting fluids, among other effects, increases the heat capacity of the fluid significantly. To that effect, the appropriate concentration of nanofluids is important to prevent excess, which will lead to wastage, and to prevent using a low concentration of nanofluids, which can yield dissatisfactory results. However, besides the nanofluid input, other input parameters like the cutting speed and the feed rate are relevant in deciding the quality of products from the turning operation. Thus, investigating the turning process of the Inconel X750 with Al_2O_3 suspended nanofluids in coconut was examined to achieve the best set of parameters for the turning of the aforementioned workpieces.

Furthermore, excessive use is bound to have financial implications that come with wastage when there is no adequate insight as to the appropriate magnitude of the input parameters, such as the percentage concentration of nanofluids. This effect then becomes pronounced when production is done on a large scale. The same applies to the cutting speed, and the feed rate as a lack of optimal parameters can have adverse effects such as high surface roughness and a high level of tool wear. Then, with these defects in operations, tools will have to be replaced more frequently, and cases of defective products are bound to occur. In a study, Tosun et al. (2016) analyzed the effect of the nanofluids on the workpiece like the surface roughness. The effects of the nanofluids and their contribution to determining the tool wear and the cutting force were also investigated, thus showing that a relationship exists between the concentration of the nanofluids and the output parameters.

However, as the optimization drive for the turning process progresses, the aspect-based Taguchi optimization approaches have been newly accepted as important routes to optimizing the turning experimental parameters. The significance of aspect ratios has recently been pointed out for the performance evaluation of the turning operation for the Inconel X750 alloy (Adegoke and Oke, 2021). Besides, this application domain is gaining increasing interest daily in engineering practice (Oke and Adekoya 2022). This compels researchers to understudy and expand the frontiers of knowledge by studying the effect of aspect ratios on optimal parametric settings for the Inconel X750 alloy under lubrication operation in the turning process. Unfortunately, due to its embryonic development, scholars have left unexplained the effects of introducing the aspect ratios on the optimal parametric setting. However, the negative influence of the omission aspect ratios in the optimal parametric setting is wrong decisions, which may lead to huge profit loss. Thus, this computational anomaly must be removed for the most excellent parametric evaluation and enhancement during the turning operation for Inconel X-750 material. But to correct the deficiency, this article proposes an approach to evaluating the effects of introducing aspect ratios in turning experiments, combined with direct factors, on the optimal parametric settings. A new procedure is introduced based on the theory of averages, which

terminates with obtaining the optimal parametric values. Notice that the optimal parametric setting has the deficiency of not agreeing on an overall value by design. The over-the-factor-level framework's definition precedes the overall index for the optimal parametric setting through orthogonal array's determination and, an institution of the response table.

To form a scenario of evaluation, it was decided to limit the factor composition to five as a research strategy. Thus, each scenario consists of some direct factors, complementing two aspect ratios in most cases. Therefore, the solution proposed to correct the literature weakness of not studying the effects of introducing the aspect ratios into the Taguchi methods and arriving at the optimal process parameters for the turning process is to utilize a combined direct and aspect ratio-based Taguchi method, Taguchi-Pareto, and Taguchi-ABC methods. This approach aids in finding the optimal cutting for fraternal and percentage concentration of nanofluids that will yield the possible minimal cutting force, surface roughs, and wear. The Taguchi method of analysis has its primary aim at the reduction of anomalies (Investopedia, 2021). It is a widely used method of analysis that facilitates the investigation of experimental processes to discover the optimal levels. The Taguchi-Pareto and the Taguchi-ABC methods are enhancements that introduce prioritization into the analysis frameworks. The three methods require a few experiments to be performed (Roy and Mandal, 2019). In summary, this paper aims to combine the input parameters, namely the cutting speed, the feed rate, and the concentration of Al_2O_3 suspended nanofluids in coconut oil, to optimize the cutting force, surface roughness, and tool wear in the turning of Inconel X 750 alloy by introducing direct and aspect-based Taguchi methods.

2. LITERATURE REVIEW

2.1. General

In this section, an effort is invested in analyzing the current literature on the wide aspects of titanium-nickel-Inconel-based alloys, cutting parameters in machining, cutting fluids, and minimum quantity lubrication methods parametric optimization. In this perspective, Pervaiz et al. (2013) studied the machinability of titanium and nickel alloys while focusing on variable parameters such as cutting tool materials, associated wear mechanisms, failure modes, and novel tooling techniques. As reported, Mahesh et al. (2021) investigated a profound insight into heat generation during the machining of Inconel 18, and its influence on diverse machining results exists. Furthermore, this work studied some possibilities to reduce the cutting temperature by emphasizing different machining methodologies, e.g., machining and texturing. An extensive study was conducted by Daniel et al. (2009) that investigated the machining of shape memory alloy-based Nitinol (NiTi) due to its ductility and serious strain hardening. This work focused on testing different cutting edges and grinding parameters to optimize cutting response on NiTi blades intended for endovascular tests with rotating blades revealed the best response using cutting edges for the punching process (N150N vs. 200; n

= 7). Zaman et al. (2021) investigated the optimization of cooling/lubrication environment, speed, and feed accomplished for minimum cutting temperature, roughness, and cutting force along with maximum MRR and chip thickness ratio in turning 42CrMO₄ alloy steel. Considering three multi-variant hybrid techniques, Taguchi-based based PCA-GRA, PCA, MOORA, and DEAR. The DEAR gives the best result because it is the computationally simplest multi-response optimization method; however, the limitation of the DEAR method is that it can work for the problem having conflicting objectives.

Prashanthakumar et al. (2021) focused on studying the significance of aluminum oxide (Al₂O₃) and copper oxide (CuO) nano-cutting fluids under Minimum Quantity Lubrication (MQL) processes in turning DSS-2205. The input parameters introduced to this work are different levels of percentage concentration of the cutting fluids, speed, feed rate, and depth of cut, which ANOVA analyzes to determine effective machining parameters for cutting force, temperature, and surface roughness. The experimental response showed that Al₂O₃ nanofluid gives a better response by reducing the cutting force with improved surface roughness. In contrast, nanofluid reduces the cutting temperature multi-response optimization is also carried out to minimize the responses through Desirability Function Analysis (DFA) for the two fluids. The optimum parametric setting for Al₂O₃ nanofluid are 0.7% of nanoparticles, 64.74m/min of speed, 0.051mm/rev of feed, and 0.4mm of the depth of cut. OPS for CuO are 0.634% of nanoparticles, 59.92m/min of speed, 0.053mm/rev of feed rate and 0.4mm of DOC, respectively.

Singh et al. (2022) examined the review of important published works on using mono/hybrid nano cutting fluids with the MQL technique at various processing parameters in different metal cutting operations. The study reveals an effective reduction in cutting forces, the temperature at the cutting zone, tool wear, and friction coefficient to enhance improvement in surface quality by increasing nano-hybrid, nanoparticles enriched cutting fluid in minimum quality lubrication (MQL) technique. Das et al. (2020) investigated the effect of different kinds of nanofluids on the machinability when machining AIS14340 alloy with hard turning making use of the minimum quantity lubrication (MQL) technique. Observing the influence of these diverse fluid properties, such as thermal conductivity, viscosity, surface tension, and contact angle, and analyzed. Each nanoparticle is dispersed, particles like ZnO, CuO, Fe₂O₃, and Al₂O₃ in deionized water. Among these fair nanofluids observed, CuO nanofluid gives the best response, then by ZnO nanofluids, but Al₂O₃ gives the worst of the responses. Ishfaq et al. (2019) investigated the cutting of stainless clad steel, focusing on increasing the material removal rate (MRR) with a minimum kerf taper. The input parameters used are stand-off distance, abrasive mass flow, water pressure, and traverse speed, then analyzed with ANOVA (analysis of variance). The abrasive mass flow and traverse rate showed the best response as the main factors for the response. Hamza et al. (2021) studied the influence of processing parameters such as

microstructural, mechanical, and corrosion properties of additively manufactured alloys. In addition, the discussion of the influence of heat treatment on Amed (Additively manufactured) alloy is also emphasized. In conclusion, the laser power had maximum effect on the microstructure. Heat treatment supplied to 316L, Ti6Al4V, Al.S, 10mg, and Inconel 718 influences the mechanical properties.

Khan et al. (2021) embarked on further study of the characteristics of post-processing operations and integrity properties of laser power bed fusion (LPBF) as-built parts factors like corrosion, wear resistance, surface roughness, microhardness, mechanical strength, and microstructure results of post-processing operations are also considered in comparison with the as-built and conventional condition for various engineering materials. Wronski (2013) studied the reviews that deal with diverse materials developed for clean energy storage, which is hydrogen energy storage but not all. This work encompasses hydrogen gas storage alloys and intermetallic used for electrochemical hydrogen storage. The research complemented a discussion of present trends in assessing materials requirements for batteries and fuel cells for electric vehicles and telecommunication. The research also discussed the aspects of recycling and life-cycle analysis.

2.2. Observations from the literature review

By the conduct of the literature survey, the emerging observations are as follows:

1. The literature review shows that tool materials impact the machinability of difficult-to-machine materials such as titanium and nickel-oriented alloys. In this instance, machinability parameters were associate with tool materials, mechanism of wear, and tool failure attributes.
2. Regarding parametric optimization using the Taguchi method and its variants of Taguchi-Pareto and Taguchi-ABC methods, several challenges such as influences on the choice and combination of aspect ratios with direct factors, effects of economic factors such as inflation and interest rate factors, the influence of imprecision and uncertainty on the optimal parametric settings remain issues of interest and require solutions.
3. The literature review indicated that very scanty efforts regarding the application of aspect ratios exist; only one report exists in the turning operations domain. However, turning operation is one of the most prevalent machining activities in the manufacturing domain, which experience tremendous volumetric counts of activities and high economic dividends for the workshops. Thus, urgent attention is required for this mechanical-based operation of turning.
4. It is that optimal parametric setting should be a reference point for setting machining standards.

3. METHODOLOGY

This section is devoted to the procedures which make

up the method to understand the effect of aspect ratio introduction into the factor-level framework on the outcome of the optimal parametric settings when each of the three methods of Taguchi; Taguchi-Pareto, and Taguchi-ABC are used. The premise is that for effective results that could be relied upon, the aspect ratios that typically represent the highest performance threshold of each parameter should be integrated with the direct factors in the factor-level framework. In this article, being limited to only three factors, namely the concentration of the nanofluids, cutting speed, and feed rate, the aspect ratios that the authors are restricted to are the proportions of each of the mentioned factors to one another only to the first power, including the reciprocals of these earlier mentioned aspect ratios.

3.1. Procedures for the method

The procedures used to implement the method of analysis in this article are as follows:

- Step 1. Extraction of optimum parametric values in all the alternatives
- Step 2. The extracted optimal parametric values are used to generate factors for the mean analysis.
- Step 3. Summation of the extracted values
- Step 4. The summation is divided by the number of factors, which is the mean/average of the optimal parametric setting
- Step 5. The mean analysis is done for both combined direct original parameters and aspect ratio, to direct original parameters only
- Step 6. The mean values obtained for combined direct original parameters and aspect ratio are thus compared with the mean values of original direct parameters only by obtaining the difference.

The procedure outlined in this section, which is to demonstrate the effect of aspect ratios on the optimal parametric setting, is a route to implementing the results obtained from the Taguchi, Taguchi-Pareto, and Taguchi-ABC methods. The Taguchi method is the classical approach to analyzing the influence of aspect ratios on the optimal parametric settings by establishing a mean value with which the results may be compared. However, it is known that to avoid wasting valuable energy and time on parameters that are not greatly important or consume significant attention that should be conserved or focusing on parameters that are not as vital as others, Pareto analysis as a prioritization tool may be introduced. This allows the process engineer to make beneficial decisions about the turning process. Also, with the need to manage more important parameters closely, the ABC analysis method was introduced and amalgamated with the Taguchi method as the Taguchi-ABC method. Considering the Taguchi-Pareto or Taguchi-ABC method, the observation of the greatest overall enhancement is possible.

3.2. Research strategy

To explain the research strategy used in this article, it is known that Venkatesan et al. (2019), whose data is used for analysis in this work, considered only three factors in

their factor-level framework. These are the percentage concentration of the nanofluid used in the turning process, the cutting speed in the turning operation, and the feed rate. Thus, the factor-level framework considered is referred to in this article as traditional, and the type of factors discussed is the direct factors. However, the platform developed for the factor-level definition used in this article considers the combination of direct factors and aspect ratios. In the first instance, three factors should be considered in each formulation, notably the concentration of the nanofluid, feed rate, and cutting speed. The second instance consists of the aspect ratios, which may be formulated as follows. For each of the three direct factors, aspect ratios involving each factor relative to others may be developed. This leads to six different aspect ratios that are candidates for testing the proposed method. This means that to proceed with the factor-level table development according to the proposed method, the three direct factors will be combined with the six aspect ratios for a total of nine factors. But this is not all as more the aspect ratio development is possible.

Consider the case in which only the numerator of the six aspect ratios proposed earlier is squared. This gives rise to six other aspect ratios. Then to formulate the factor-level table, a longer list of factors is required consisting of three factors at the initial instance, six factors at the second instance, and six factors at the third instance to make up fifteen factors. But it does not end this way as more aspect ratios could be formed using the products of factors, their squares, and cubes. If these latter cases are considered, the number of factors to qualify for inclusion into the factor-level table may be in multiple tenths, and it is not feasible to establish an orthogonal matrix for this based on the limitation of the existing experimental design software such as Minitab 16 that only accepts and interprets a few factors in the development of its orthogonal array.

Now with the explanation of the complexity involved in computing the optimal parametric settings using the Taguchi methods of the classical Taguchi, Taguchi-Pareto, and Taguchi-ABC methods, it is essential to develop a simplified combination method involving all the three direct factors and only two of the aspect ratios featured in each formulation that totals up to five factors. The research strategy adopted in the present article is the limitation of these multiple choices of direct parameters and aspect ratios to a reduced number of five factors each time.

4. RESULTS AND DISCUSSIONS

4.1. Description of method

A scenario describes the combination of direct/indirect and aspect ratio-based factors. However, based on the direct factors established to represent the turning process, the total number of factors generated for each scenario is five. Alternatives 1 to 6 were developed to contain three direct factors each, and the remaining two factors are obtained from the aspect ratios involving the three initially defined direct factors. Furthermore, for alternatives 7 to 12, the first three factors in each scenario are the reciprocals of the direct factors. In comparison, the

rest two factors are aspect ratios of the three direct factors. In all, twelve scenarios were developed and evaluated for effect analysis. To evaluate each scenario, the factors comprising direct and indirect factors were first established and their levels specified. Orthogonal arrays are then established. Afterward, the criteria for the signal-to-noise evaluation were specified as one or a combination of the smaller-the-better, larger-the-better, or the nominal the best. The signal-to-noise ratios were then determined, while the summarized signal-to-noise ratios as a response table were established. From this, the optimal parametric settings are established and translated into a global mean value. Comparisons of mean values for the combined factors and direct factors only were made for each scenario and all scenarios on average.

4.2. Optimum parametric values result in analysis

The experimental result extracted from Venkatesan et al. (2019)

Table 1. The results of the experimental trials, Venkatesan et al. (2019)

Level	Percentage concentration (%)	Cutting speed (m/min)	Feed rate (mm/rev)
1	0.25	40	0.14
2	0.50	60	0.17
3	1.00	100	0.20

The optimum parametric setting is a special technique introduced to experimental analysis which helps a researcher to be able to select the best/significant value out of the parameters that made up the experimental runs. It is best obtained by finding the maximum value of each factor based on levels. This work comprises three parameters: the percentage concentration of nanofluid used, the cutting speed of the machine, and the feed rate of the turning operation, as shown in Table 1. In addition, the consideration of the aspect ratios of the primary parameters, as highlighted earlier, is the possible ratios of

the primary parameters such as C/V , F/V , C/F , V/F , V/C , and F/C , respectively. After the experimental runs for the entire twelve alternatives, this work focused on considering the optimal parametric settings obtained from the response evaluations of the whole experimental runs. The optimum parametric setting is selected based on the levels considered in the experiment, which are three. The optimum parametric setting could fall on either of the three levels of the experiment. More so, the optimum parametric setting being the maximum value within each particular factor, is selected as the optimum parametric value. This means that value is the most beneficial value, and the level at which that value is found is the benefit level for the turning operation. At this notion, we can also say that the optimum parametric setting is the level/value technique.

4.2.1. Mean method of optimal parametric setting (OPS)

The optimum parametric settings across all the response evaluation tables were extracted and made used to constitute parameters in another analysis known as mean analysis of optimal parametric settings, Table 2.

As seen from Table 2, focusing on Taguchi experimental runs, the optimal parametric values obtained from the response evaluation were selected in correlation to the initial value/level table before the experimental runs. The mean analysis is also conducted considering only the direct standard parameters, as shown in Table 3.

The followings are the findings from the analysis using the mean method, where the values of the optimal parametric settings are averaged to obtain a reference point for comparison. For all the twelve alternatives, the differences in means when the mean of the optimal parametric setting for the combined direct factors and aspect ratios were compared to when only direct factors were analyzed. It was observed to be the following for alternatives 1 to 12, respectively: -5.3873 , 52.1067 , 14.5507 , 14.5114 , -5.2766 , -5.0309 , -1.2014 , 56.8287 , 19.3687 , 19.3291 , -0.5589 and -0.3129 .

Table 2. Combined direct parameters and aspect ratios mean analysis (Taguchi method optimum parametric value normalization)

Alternative	Optimal parametric setting (OPS) values					Σ OPS	Mean value
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5		
1	0.25	40.00	0.17	0.01	0.004	40.43	8.09
2	0.25	40.00	0.20	1.79	285.714	327.95	65.59
3	1.00	40.00	0.17	100.00	0.200	141.37	28.27
4	1.00	40.00	0.17	100.00	0.004	141.17	28.23
5	0.25	40.00	0.17	0.56	0.004	40.98	8.20
6	0.25	40.00	0.17	0.01	1.786	42.21	8.44
7	4.00	0.03	5.00	0.01	0.004	9.03	1.81
8	0.01	0.03	5.00	1.79	285.71	292.54	58.51
9	0.01	0.03	5.00	100.00	0.200	105.24	21.05
10	0.01	0.03	5.00	100.00	0.002	105.04	21.01
11	0.01	0.03	5.00	0.56	0.002	5.60	1.12
12	0.01	0.03	5.00	0.01	1.786	6.83	1.37

Key: n, number of factors is 5

Table 3. Direct parameters mean analysis (Taguchi only)

Alternative	Direct parametric values			Σ OPS	Mean Value
	Factor 1	Factor 2	Factor 3		
1	0.25	40.00	0.17	40.42	13.47
2	0.25	40.00	0.20	40.45	13.48
3	1.00	40.00	0.17	41.17	13.72
4	1.00	40.00	0.17	41.17	13.72
5	0.25	40.00	0.17	40.42	13.47
6	0.25	40.00	0.17	40.42	13.47
7	4.00	0.03	5.00	9.03	3.01
8	0.01	0.03	5.00	5.04	1.68
9	0.01	0.03	5.00	5.04	1.68
10	0.01	0.03	5.00	5.04	1.68
11	0.01	0.03	5.00	5.04	1.68
12	0.01	0.03	5.00	5.04	1.68

Key: n, number of factors is 5

Table 4. The Taguchi-Pareto difference in mean analysis

Alternative	Mean Value 1	Mean Value 2	Difference
1	20.09	33.48	-13.39
2	65.58	13.47	52.11
3	40.20	13.58	26.65
4	40.09	13.47	26.61
5	20.20	33.47	-13.28
6	20.67	33.47	-12.80
7	1.98	3.30	-1.32
8	59.73	3.72	56.01
9	34.05	3.30	30.75
10	33.98	3.30	30.68
11	1.27	2.00	-0.73
12	2.57	3.30	-0.73

4.2.2. Taguchi-Pareto mean differences analysis

The mean of the optimal parametric settings of the Taguchi-Pareto response evaluation for combined direct standard factors and aspect ratios has been compared with when direct standard parameters are only considered, as shown in Table 4.

Furthermore, some interesting findings were obtained from the analysis using the mean method, where the values of the optimal parametric settings are averaged to achieve a reference point for comparison. Since twelve alternatives are considered, the differences in means when the mean of the optimal parametric setting for the combined direct factors and aspect ratios were obtained and weighed when only direct factors were examined. It was found that for the consecutive mentioning of alternatives 1 to 12, the following values are obtained: -13.3915, 52.1107, 26.6453, 26.6123, -13.2757, -12.7998, -1.3170, 56.0121, 30.7490, 30.6827, -0.7329 and -0.73150.

4.2.3. Taguchi-ABC (region A) mean differences analysis

The mean of the optimal parametric settings of the response evaluation of Taguchi - ABC (region A) for combined direct standard factors and aspect ratios is compared with when direct standard parameters only are considered, as shown in Table 5.

Besides, the results obtained from the analysis using the mean method, where the values of the optimal parametric settings are averaged to achieve a reference point for comparison, are stated. Here, all the twelve alternatives considered are analyzed regarding their differences in means when the mean of the optimal parametric setting for the combined direct factors and aspect ratios were obtained and weighed when only direct factors were examined. It was shown that for alternatives 1 to 12, the following values are obtained: -5.3874, 52.0813, 26.7227, 26.6114, -5.2766, -5.0309, -1.3192, 56.0110, 18.7910, 18.6797, -1.2084 and -0.1993, respectively.

4.2.4. Taguchi-ABC (region B) mean differences analysis

The mean of the optimal parametric settings of the response evaluation of Taguchi - ABC (region A) for combined direct standard factors and aspect ratios is compared with when direct standard parameters only are considered, as shown in Table 6.

Moreover, the followings are the findings from the analysis using the mean method, where the values of the optimal parametric settings are averaged to obtain a reference -point for comparison. For all the twelve alternatives, the differences in means when the mean of the optimal parametric setting for the combined direct factors and aspect ratios were compared to when only

direct factors were analyzed. It was observed to be the following for alternatives 1 to 12, respectively: -18.6978, 38.9311, 5.3120, 5.2007, -18.7314, -18.2101, -0.8011, 56.9278, 23.3087, 23.1974, -0.7348 and -0.4445.

4.2.5. Taguchi-ABC (region C) mean differences analysis

The mean of the optimal parametric settings of the response evaluation of Taguchi - ABC (region C) for combined direct standard factors and aspect ratios are compared with when direct standard parameters only are considered, as shown in Table 7.

Still, several interesting findings were obtained from the analysis using the mean method, where the values of the optimal parametric settings are averaged to achieve a reference point for comparison. Since twelve alternatives are considered, the differences in means when the mean of the optimal parametric setting for the combined direct factors and aspect ratios were obtained and weighed when only direct factors were examined. It was found that for the consecutive mentioning of alternatives 1 to 12, the following values are obtained: -8.1494, 49.9909, 11.9600, 11.8487, -8.1114, -7.5625, -1.0854, 57.0549, 19.0241, 18.9128, -1.0474 and -0.2118.

4.3. Novelty of the study

In the optimization research arena, it is accepted that optimal parametric settings represent the best benchmark of performance with which each factor's effectiveness

could be judged. This type of research dominates the turning operations for dry cutting, wet cutting, and minimum quantity lubrication processed. However, for all studies, researchers have not overcome the limitations of having a single value representing the optimal parametric settings for the process regarding all factors. At best, the interpretation of the optimal parametric setting is done with each factor having a threshold of value during the online machining operations are made.

Notwithstanding, according to the authors' knowledge, previous authors have utilized the normalization concept in multi-criteria decision-making to aggregate scores of factors, which have different values, into a single index. While researchers in the turning process are still confronted with the inability to agree on a single index of measurement for optimal parametric settings, no work has been dedicated to studying the development of such an index and the effect it has on the optimal parametric setting. But while the normalization concept is acceptable in turning operations, it is thought that introducing the idea of averages of the parametric values through robust the idea of the theory of averaged and normalization provides a reliable index to the transaction the optimal parametric setting into. Thus, the novelty of this article is the introduction of the theory of average to the optimal parametric setting values to transform multiple and diverse unit-based factors into a single, unitless index, to represent a benchmark value for comparison of results.

Table 5. Taguchi-ABC (region A) difference in mean analysis

Alternative	Mean Value 1	Mean Value 2	Difference
1	8.09	13.47	-5.39
2	65.62	13.55	52.08
3	40.20	13.47	26.72
4	40.08	13.47	26.61
5	8.20	13.47	-5.28
6	8.44	13.47	-5.03
7	1.98	3.30	-1.32
8	59.73	3.72	56.01
9	22.09	3.30	18.79
10	21.98	3.30	18.68
11	2.09	3.30	-1.21
12	2.80	3.00	-0.20

Table 6. Taguchi-ABC (region B) difference in mean analysis

Alternative	Mean Value 1	Mean Value 2	Difference
1	12.23	20.38	-8.15
2	70.37	20.38	49.99
3	32.34	20.38	11.96
4	32.23	20.38	11.85
5	12.27	20.38	-8.11
6	12.82	20.38	-7.56
7	1.63	2.72	-1.09
8	59.77	2.72	57.05
9	21.74	2.72	19.02
10	21.63	2.72	18.91
11	1.67	2.72	-1.05
12	1.79	2.00	-0.21

Table 7. Taguchi-ABC (region C) difference in mean analysis

Alternative	Mean Value 1	Mean Value 2	Difference
1	12.23	20.38	-8.15
2	70.37	20.38	49.99
3	32.34	20.38	11.96
4	32.23	20.38	11.85
5	12.27	20.38	-8.11
6	12.82	20.38	-7.56
7	1.63	2.72	-1.09
8	59.77	2.72	57.05
9	21.74	2.72	19.02
10	21.63	2.72	18.91
11	1.67	2.72	-1.05
12	1.79	2.00	-0.21

5. CONCLUSION

In the present work, the effect of aspect ratios on the optimal parametric setting using the Inconel X750 alloy under nanofluids was investigated under the influence of experimental data from the turning literature. The differences between the means of the combined factors and direct factors alone were examined for twelve experimental sceneries. Three Taguchi methods are the classical Taguchi, Taguchi-Pareto, and Taguchi-ABC. However, by examining the obtained results from this study, the following conclusions are valid:

1. The mean method of establishing a composite index for optimal parametric settings through the averaging of the factor values and obtaining the differences between the results of the combined factors and direct/reciprocals of direct factors is a feasible approach to evaluating the effects of aspect ratios on the optimal parametric settings during the turning of Inconel X 750 alloy using nanofluids.
2. The difference in means between the combined factors and the director factors on the one hand. In contrast, the reciprocals of the direct factors, on the other hand, show staggering figures of negative and positive values. This implies that the effect of aspect ratios could be random and depends on the experimental data being examined.
3. The paucity of knowledge on the introduction of aspect ratios in combination with direct factors has triggered the use of direct factors alone for optimal process parametric determination problems in turning operations.
4. An integrated direct factor and aspect ratio approach to parametric determination will provide better results than the direct factor approach in Taguchi methodical developments.

There are numerous promising extensions of the present study, including the following. The proposed research could demonstrate the possibility of introducing economic factors such as inflation and interest rates as multiplicative factors to the aspect ratios. The effects of these new factors could then be explored for the same problem examined in the present study. In the future, researchers should explore the chance of introducing different variants of aspect ratios into the factor-level framework. In the present article, only the aspect ratios

of the direct factors in their simplest form are considered, but more challenges than these need to be solved. For instance, C, V, and F were used to represent the direct factors, and C/V, V/C, C/F, and F/V were considered as aspect ratios; what about squaring or putting cubes as powers of these later mentioned aspect ratios and their effects on the optimal parametric setting analyzed under the Taguchi, Taguchi-Pareto and Taguchi-ABC methods? Future researchers may also consider expanding the number of factors (direct and aspect ratios) considered at a time to interpret the orthogonal matrix. In this article, only five factors were considered. However, future investigators may attempt the six factors above to determine the largest possible scope that the factors and levels may absorb to study the effects of direct factors and aspect ratio combination on the optimal parametric settings using the Taguchi methods and their variants.

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