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DISCOVERING THOUGHTS AND INVENTING FUTURE

Highlights

Electromagnetic Fuel Saver

Multi-objective Optimisation

Ethanol Emulsion

SWET Technique

Assembly Line

Volume 12 | Issue 6 | Version 1.0

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Mechanical and Mechanics Engineering

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Electromagnetic Fuel Saver for Enhanching The Performance of The Diesel Engine

By Houtman P. Siregar & Rufinus Nainggolan

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Abstract - This article is devoted to the production and testing of the performance of electromagnetic fuel saver. Purpose of the work is to analysis effect of varying of core of electromagnetic fuel saver to the performance of the internal combustion diesel engine. Materials for core of electromagnetic fuel saver are made of plain carbon steel and copper. Diameters of the wire winding, which is used in the research, are 0.25 mm and 0.35 mm. Speed of the engine, and number of coil which is coiled in the winding core of the fuel saver are chosen as the testing variables. The produced fuel saver is tested in the laboratory and on the road in the traffic jam condition and in the highway. Measured variables in the laboratory is the specific fuel consumption and measured variable for road testing is fuel consumption. From this work is obtained that the performance of the electromagnetic fuel saver which use copper core is better than the electromagnetic fuel saver which use steel core and permanent magnet.

Keywords : *Electromagnetic fuel saver, specific fuel consumption, number of coil, core material, wire winding diameter.*

GJRE-A Classification : *FOR Code: 091305*

ELECTROMAGNETIC FUEL SAVER FOR ENHANCHINGTHE PERFORMANCE OF THE DIESEL ENGINE

Strictly as per the compliance and regulations of:

Electromagnetic Fuel Saver for Enhanching The Performance of The Diesel Engine

Houtman P. Siregar [α] & Rufinus Nainggolan [σ]

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Keywords : Electromagnetic fuel saver, specific fuel consumption, number of coil, core material, wire winding diameter.

I. Introduction

Nowadays for solving the crisis of energy in Indonesia, many works are done to search the alternative source of energy. Simultaneously the researcher tries to create the gadget which can save the fuel consumption for automobile.

Purpose of the work is to produce and analysis the performance of the electromagnetic fuel saver for automotive diesel engine and to analysis effect of the change of the core of electromagnetic fuel saver to the performance of the diesel engine.

The fuel saver which is based on permanent magnet has sold in the market and its performance has tested [4, 5]. In comparison to the former fuel saver, in the considered work is produced fuel saver which is based on electromagnetic induction. The considered work is the continuation of former works [1, 2, 3].

II. Working Theory Of The Electromagnetic Fuel Saver

The combustion engine vehicle efficiency is about 9 %. This means that our car consume more energy than it converts in to movement. In other words, we pay more energy than we use. In the article we describe method and gadget for improving the combustion of fuel in the internal combustion diesel engine of automobiles where the fuel employed is liquid [4, 5].

Applying a magnetic field to ionizing fuel to be fed to combustion devices we can ensure more complete combustion, obtaining a maximization of the fuel economy, improving the fuel efficiency and reducing polluting emissions. The fuel is subject to the lines of forces from electromagnetic magnet mounted on fuel inlet lines. Most fuels for internal combustion engines are liquid. But liquid fuels don't combust till they are vaporized and mixed with air. Currently regulated gas emissions from motor vehicles are unburned hydrocarbon (HC), carbon monoxide (CO), and oxides of nitrogen (NOx).

Fuel mainly consists of hydrocarbons. Groupings of hydrocarbons, when flowing through a magnetic field, change their orientations of magnetization in a direction opposite to that of the magnetic field. The molecules of hydrocarbon change their configuration. At the same time intermolecular force is considerably reduced or depressed. These mechanisms are believed to help to disperse oil particles and to become finely divided. The resultant conditioned fuel electromagnetized burns more completely, producing higher engine output, better fuel economy, more power and most importantly reduces the amount of hydrocarbons, carbon monoxide and oxides of nitrogen in the exhaust. Another benefits if these devices is that magnetically charged fuel molecules with opposite polarities dissolve carbon build-up in carburettor jets, fuel injectors, and combustion chambers help to clean up the engine and maintain the clean condition.

III. Methodology

In figure 1 is shown flowchart of the considered work. First of all it is designed the fuel saver which is based on electromagnetic and then it is produced according to the determined specification. Speed of the engine, diameter of the wire winding, core materials, and number of coil of winding of fuel saver are chosen as the testing variables. The performance of fuel saver, which has produced, is tested in the laboratory of the

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internal combustion engine rig. Performance of the produced fuel saver which is installed in the fuel line of internal combustion engine rig is compared to the performance of the standard internal combustion engine rig (without installing fuel saver in the fuel line). Performance of the produced fuel saver is compared to the performance of the permanent magnet fuel saver, which has sold in the market. And then results of the work are discussed and finally the conclusions are drawn.

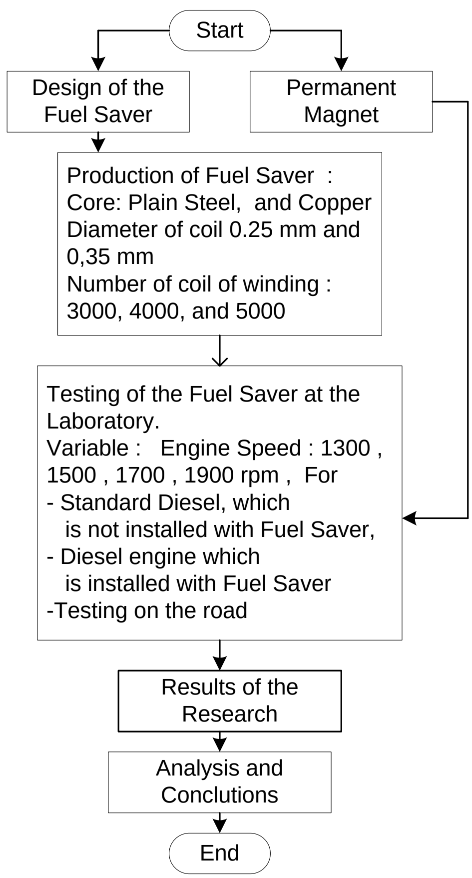

Fig. 1 : Flowchart of the proposed research

IV. Results and Discussion

In the considered work, terminology of fuel saving means fuel consumption of fuel saver which is based on electromagnetic induction minus fuel consumption of diesel engine which is not installed with fuel saver (standard). Difference of the fuel consumption between e standard diesel engine and diesel engine which is installed with fuel saver may be positive and negative value. Negative value means more consume fuel and positive value means less consume fuel than standard diesel engine.

In the figures use some abbreviations. The meanings of each abbreviation are as follows. Cu-35/5000 means that the electromagnetic fuel saver use core of copper, diameter of wire 0.35 mm and number of coil 5000 turns. St-25/5000 means that the electromagnetic fuel saver use core of plain carbon steel, diameter of wire 0.25 mm and number of coil 5000 turns. PM means permanent magnet.

In the figure 2 up to figure 6 are drawn results of laboratory test of diesel engine. And in the figure 7 is drawn result of the road test for the best gadget and permanent magnet.

In the figure 2 is drawn results of laboratory test for diesel engine which relate the percentage of specific fuel consumption (SFC) saving for average speed of rotation of engine for electromagnetic fuel saver, which use diameter of wire 0.25 mm and steel core versus number of winding. As it is shown in figure 2 that electromagnetic fuel saver which use number of coil or winding 5000 turns is better in fuel saving than the fuel saver which uses number of coil 3000 and 4000 turns. Electromagnetic fuel saver which uses number of coil or winding 5000 can save specific fuel consumption 9.80 %. For number of winding 3000 and 4000 turns can save SFC, respectively, 7.55% and 4.76%.

In the figure 3 is drawn results of laboratory test for diesel engine which relate the percentage of specific fuel consumption (SFC) saving for average speed of rotation of engine for electromagnetic fuel saver which uses diameter of wire 0.35 mm and steel core versus number of winding. As it is shown in figure 3 that electromagnetic fuel saver which uses number of coil or winding 3000 turns is better in fuel saving than the fuel saver which uses number of coil 4000 and 5000 turns. Electromagnetic fuel saver which uses number of winding 3000 turns can save specific fuel consumption 6.77 %. For number of winding 4000 and 5000 turns can save SFC, respectively, 6.14% and 5.93%.

In the figure 4 is drawn results of laboratory test for diesel engine which relate the percentage of specific fuel consumption (SFC) saving for average speed of rotation of engine for electromagnetic fuel saver which uses diameter of wire 0.25 mm and copper core versus number of winding. As it is shown in figure 4 that electromagnetic fuel saver which uses number of coil or winding 5000 turns is better in fuel saving than the fuel saver which use number of coil 3000 and 4000 turns. Electromagnetic fuel saver which uses number of winding 5000 can save specific fuel consumption 9.54 %. For number of winding 3000 and 4000 turns can save SFC, respectively, 4.77% and 7.95%.

In the figure 5 is drawn results of laboratory test for diesel engine which relate the percentage of specific fuel consumption (SFC) saving for average speed of rotation of engine for electromagnetic fuel saver which uses diameter of wire 0.35 mm and copper core versus number of winding. As it is shown in figure 5 that electromagnetic fuel saver which uses number of coil or winding 5000 turns is better in fuel saving than the fuel saver which uses number of coil 3000 and 4000 turns. Electromagnetic fuel saver which uses number of winding 5000 turns can save specific fuel consumption 11.53 %. For number of winding 3000 and 4000 turns can save SFC, respectively, 6.76% and 8.35%.

In the figure 6 is drawn graph of comparison of optimal percentage of specific fuel consumption (SFC) saving for average speed of rotation of engine versus type of gadget. As it is shown in figure 6 that gadget which uses copper core is better in fuel saving than the gadget which uses steel core and permanent magnet. Once more the electromagnetic fuel saver is better in fuel saving than the permanent magnet. As shown in figure 6 that the electromagnetic fuel saver which uses copper core, number of coil 5000, and diameter of wire winding 0.35 mm can save specific fuel consumption 11.53 %. Electromagnetic fuel saver which uses steel core, number of coil 5000 turns, and diameter of wire winding 0.25 mm can save specific fuel consumption 9.80 %. But gadget which uses permanent magnet just can save specific fuel consumption 8.53%.

In the figure 7 is drawn results of road test for diesel engine which relate the percentage of fuel consumption saving for optimal electromagnetic fuel saver and permanent magnet. It is seen from figure 7 that the electromagnetic fuel saver which uses copper core, number of coil 5000 turns, and diameter of wire winding 0.35 mm can save fuel consumption 31.50 %. Electromagnetic fuel saver which uses steel core, number of coil 5000 turns, and diameter of wire winding 0.25 mm can save fuel consumption 28.40 %. But gadget which uses permanent magnet just can save specific fuel consumption 25.30%. In this case, the best gadget is the electromagnetic fuel saver which uses copper core.

As we know that the more the number of winding the stronger the magnetic force. So the stronger magnetic force will give stronger induction to solar fuel and resulting in complete combustion process. So the cluster of solar fuel is fully oriented and the configuration of fuel is changed. At the same time intermolecular force is considerably reduced or depressed. These mechanisms are believed to help to disperse oil particles in this case and to become finely divided and make easy to mix compressed air with solar fuel and resulting in complete combustion process. The resultant conditioned fuel burns more completely, producing higher engine output, better fuel economy, and more power.

In the work, electromagnetic fuel saver which uses copper core is better than electromagnetic fuel saver which uses steel core and permanent magnet. It seems that the copper core is more effective in inducing magnetic force than steel core. This phenomenon is an anomaly in this work, because according to the theory of magnet that ferrous material (steel) is better in inducing magnetic force than nonferrous material (copper). In this case, it seems that the strength of the magnetic force of electromagnetic fuel saver is stronger than permanent magnet fuel saver. So, the stronger magnetic force results in more complete combustion process than permanent magnet fuel saver.

So the produced electromagnetic fuel saver can significantly save consumption of fuel. Saving the fuel consumption means that the heat of combustion which is released to the atmosfere diminishing. Consequently the produced fuel saver can reduce and overcoming global warming.

In conclusion we have succeeded to produce good prototype of electromagnetic fuel saver and it has good performance. The produced fuel saver can significantly save fuel consumption for diesel engine. In addition the proposed fuel saver can improve quality of environmental and overcoming global warming.

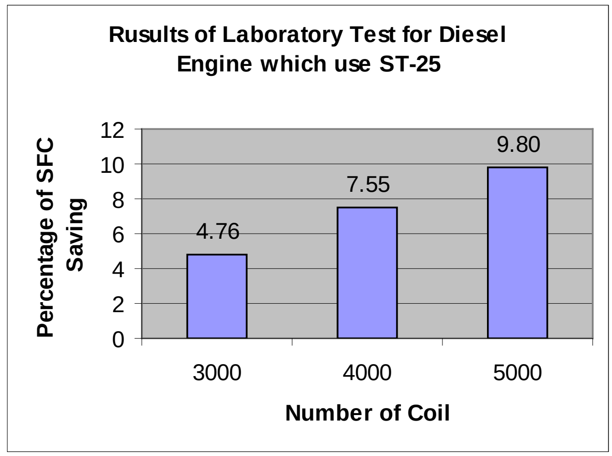

Fig. 2 : Results of laboratory test for steel core and diameter of wire 0.25 mm.

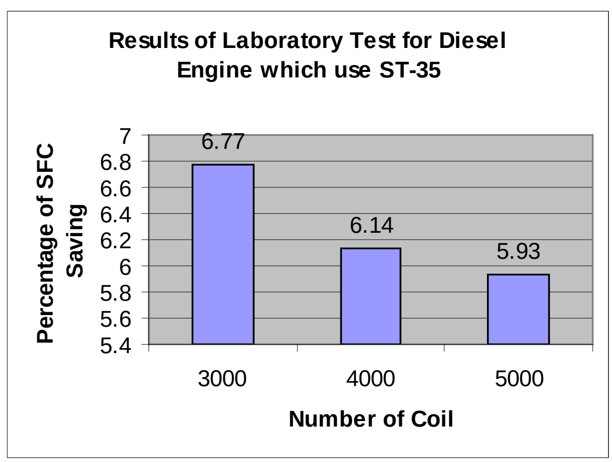

Fig. 3 : Results of laboratory test for steel core and diameter of wire 0.35 mm.

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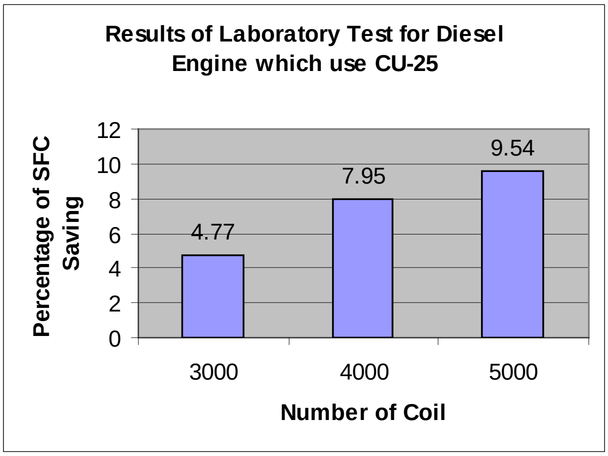

Fig. 4 : Results of laboratory test for copper core and diameter of wire 0.25 mm.

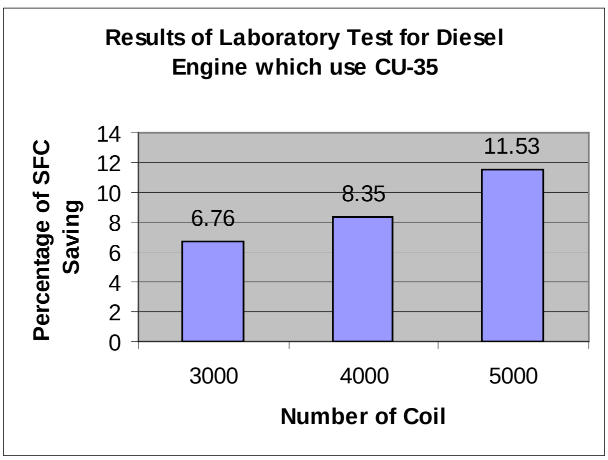

Fig. 5 : Results of laboratory test for copper core and diameter of wire 0.35 mm.

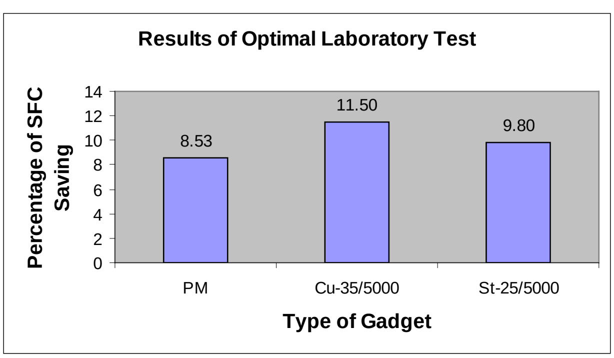

Fig. 6 : Comparison of the optimal saving in relation to the type of gadget

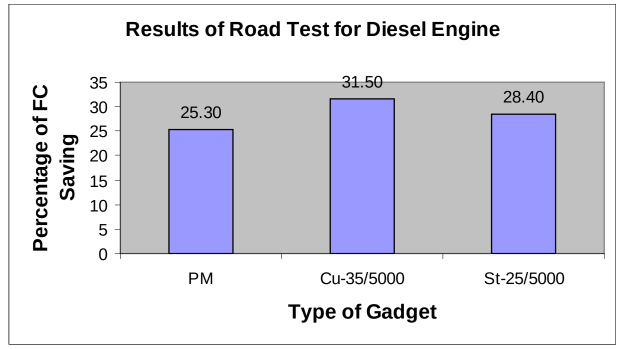

Fig. 7 : Results of road test versus type of gadget

V. Conclusions

1. The considered work has succeeded to produce fuel saver which is based on electromagnetic induction for saving the fuel consumption of diesel engine.
2. Wire diameter and number of winding of the produced fuel saver effect fuel consumption of diesel engine.
3. Laboratory testing shows that the produced fuel saver can save specific fuel consumption about 11.53 % which use diameter of wire 0.35 mm and number of winding 5000 turns, for copper core.
4. Road testing shows that the produced fuel saver can save fuel consumption about 31.53% which uses diameter of wire 0.35 mm and number of winding 5000 turns, for copper core.

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Weighted Sum Method for Multi-Objective Optimisation for Aluminium Metal Casting

By Kuldeepak & Ravi K. Sharma
Jaypee University of Engineering & Technology, Guna.

Abstract - An optimisation technique for design of gating system parameters of a cylindrical aluminium casting based on the Taguchi method is proposed in this paper. The various gating systems for a casting model of aluminium are designed. Mould filling and solidification processes of the Aluminium casting were simulated with the PROCAST, AUTOCAST, and MAGMASOFT etc. The simulation results indicated that gating system parameters significantly affect the quality of the Aluminium casting. In an effort to obtain the optimal process parameters of gating system, an orthogonal array, the signal-to- noise (S/N) ratio, and analysis of variance (ANOVA) were used to analyze the effect of various gating designs on cavity filling and casting quality using a weighting method.

Keywords : Taguchi method, Computational simulation, Optimisation, Gating system, Aluminium casting.

GJRE-A Classification : FOR Code: 091307

WEIGHTED SUM METHOD FOR MULTI-OBJECTIVE OPTIMISATION FOR ALUMINIUM METAL CASTING

Weighted Sum Method for Multi-Objective Optimisation for Aluminium Metal Casting

Kuldeepak [α] & Ravi K. Sharma [σ]

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Keywords : Taguchi method, Computational simulation, Optimisation, Gating system, Aluminium casting.

I. Introduction

A large number of experimental investigations linking gating parameters with casting quality have been carried out by researchers and foundry engineers over the past few decades (Campbell, 2003; Yang et al., 2000). Since all liquid melt required filling up the casting cavity needs to be introduced through the gating system, it has been long recognized that gating system design plays one of the key elements in casting quality. Although there are general casting design guidelines and empirical equations for the gating ratio, pouring time, and gating system dimensions, the variations in casting parameters chosen by different researchers have led to significant variations in empirical guidelines (Campbell, 1998). This also forces foundries to carry out a number of trial and error runs and create guidelines based on their own experience. Traditionally, gating system design is performed by casting process engineers based on their individual knowledge and experience. In many cases, the gating system design is not optimal and often based on trial and error practice. This leads to not only a long casting development cycle but also a low reliability of casting design due to variation of individual knowledge and experience.

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The use of a good gating system is even more important if a casting is produced by a gravity process. Since oxide formation is instantaneous in Aluminium, the design of gating system plays more important role on minimising the entrance of oxides on the surface of the molten metal into the casting and also to prevent turbulence in the metal stream caused by excessive velocities of the molten metal, free-falling of the stream while passing from one level to another, vortices formed, or abrupt changes in the flow direction (Hu and Yu, 2002; Green and Campbell, 1994). Therefore, Aluminium castings are vulnerable to certain defects such as porosity, oxide inclusions, which are known to be attributed to the faulty design of gating system with incorrect mould filling. In order to achieve a good gating system, it is necessary to start from fundamental hydraulic principles. Computer-aided casting design and simulation gives a much better and faster insight for optimising the feeder and gating design of castings (B.Ravi, 2009).

The first research showing an effect to apply a numerical optimisation methodology to optimise a gating system is due to Bradley and Heinemann in 1993 (Bradley and Heinemann, 1993). They used simple hydraulic models to simulate the optimisation of gating during filling of moulds. In 1997, MacDavid and Dantzig used a mathematical development addressing the design sensitivity within two-dimensional mould geometry. By the end of the 1990s, the computer modeling enabled visualization of mould filling to be carried out cost-effectively in casting design and optimisation of gating system. Numerical simulators based on FDM and FEM methods provide powerful means of analyzing various phenomena occurring during the casting process (McDavid and Dantzig, 1998a, b).

Dr. Genichi Taguchi has introduced several new statistical tools and concepts of quality improvement that depend heavily on the statistical theory of experimental design (Taguchi, 1998; Byrne and Taguchi, 1987). Some applications of Taguchi's methods in the foundry industry have shown that the variation in casting quality caused by uncontrollable process variables can be minimized. The casting process has a large number of parameters that may affect the quality of castings. Some of these parameters are controllable while others are noise factors. Therefore, the optimisation of casting parameters using the Taguchi method is the better choice for rapid casting quality improvement.

The purpose of this paper is to demonstrate how the application of numerical optimisation techniques can be used to develop an effective optimisation process for gating system design. Mould filling and solidification processes of the castings can be simulated with the *PROCAST, AUTOCAST, MAGMASOFT etc.* The simulation results indicated that gating system parameters significantly affect the casting quality. This virtual approach and optimisation technique can be applied to the foundry industry, which is evidently superior to typical trial-and-error approaches.

II. Design of Experiment Based on the Taguchi Method

A large number of experiments have to be carried out when the number of the process parameters increases. To solve this task, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. The S/N ratio for each level of process parameters is computed based on the S/N analysis. Regardless of the category of the performance characteristic, the larger S/N ratio corresponds to the better performance characteristic. Therefore, the optimal level of the process parameters is the level with the highest S/N ratio. Furthermore, a statistical analysis of variance (ANOVA) is performed to see which process parameters are statistically significant. With the S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design. In this paper, the gating parameter design by the Taguchi method is adopted to obtain optimal gating system in aluminium casting. The experimental layout for the four gating parameters used L9 orthogonal array.

III. Gating System Parameters and Objectives Design

The objective of the parameter design is to optimise (D.C. Montgomery, 1991) the settings of the process parameter values for improving performance characteristics and to identify the product parameter values under the optimal process parameter values. In addition, it is expected that the optimal process parameter values obtained from the parameter design are insensitive to the variation of environmental conditions and other noise factors. A cubical housing model was used as the test sand casting to understand the numerical optimisation. The three-dimensional CAD model of the test casting is shown in Fig. 1. The casting material is defined Aluminium. The process used for preparing mould cavity is sand casting. A pouring basin and tapered sprue were used and metal was introduced into the casting cavity through one runner and one ingate of rectangular cross-section. Single blind riser is used at top of the housing model.

Since the lower and wide geometry help to reduce the metal velocity and get a smooth flow into mould, the parameter ranges of the design variables. In this work gating parameters like runner height, runner width, ingate height and ingate width were changed. Remaining parameters kept constant for all the experiments. In this study, in order to evaluate the sound casting comprehensively, the optimisation criteria for the housing casting sample were defined as:(1) casting quality, and (2) casting cost. The molten metal filling velocity and casting shrinkage

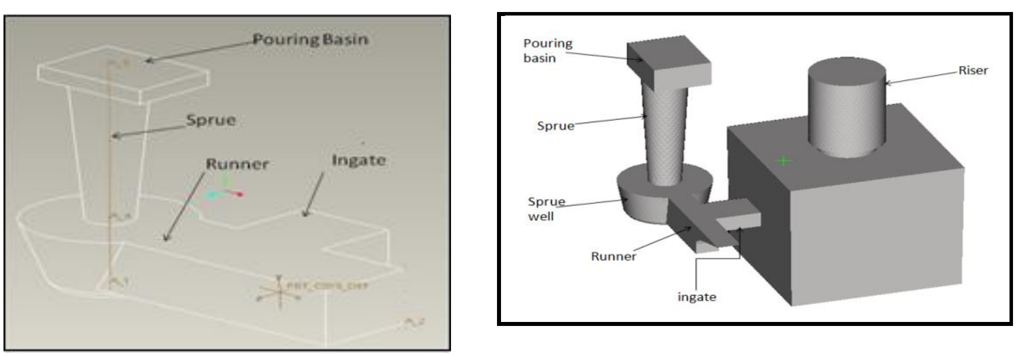

Fig.1 : 3-D Model of gating system

porosity can demonstrate the casting quality; and the casting cost characteristic can be indicated by product yield. These three characteristics acting as multiple performance objectives for evaluating different gating system designs are defined as the Eqs. (1) – (3):

$$\text{Velocity}(v) = \sqrt{v_x^2 + v_y^2 + v_z^2} \quad (1)$$

$$\text{Shrinkage Porosity}(\%) = \frac{\text{pores}}{\text{vol}_{cast}} \quad (2)$$

$$\text{Casting Yield}(\%) = \frac{\text{weight}_{cast}}{\text{weight}_{cast} + \text{weight}_{gating+riser\,system}} \quad (3)$$

Where v_x, v_y, v_z are three component of vector velocity.

IV. Analysis of the S/N Ratio With Multiple-Performance Characteristics

The Taguchi method uses signal-to-noise (S/N) ratio instead of the average value to interpret the trial results data into a value for the evaluation characteristic in the optimum setting analysis. This is because signal-to-noise ratio can reflect both the average and the variation of the quality characteristics. S/N ratio can be defined as Eq. (4)

$$\eta = -10\log(MSD) \tag{4}$$

Where MSD is the mean-square deviation for the output characteristic. The MSD for the higher-the-better quality characteristic can be expressed as Eq. (5)

$$MSD = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{T_i^2} \tag{5}$$

On the other hand, the lower-the-better quality characteristic for filling velocity and shrinkage porosity also is being taken for obtaining the optimal casting quality. The MSD for the lower-the-better quality characteristic can be expressed as Eq. (6):

$$MSD = \frac{1}{n}\sum_{i=1}^{n}S_i^2 \tag{6}$$

Where n is the total number of tests in a trial and Ti is the value of product yield and Si is the value of filling velocity and shrinkage porosity at the ith test.

The proposition for the optimisation of a gating system with multiple performance characteristics (three objective) using a weighting method is defined as

$$X=Y\times Z \tag{7}$$

$$\text{where } X=\begin{bmatrix}\eta_{1C}\\ \eta_{2C}\\ .\\ .\\ \eta_{9C}\end{bmatrix};\quad Y=\begin{bmatrix}\eta_{11}\ \eta_{12}\ \eta_{13}\\ \eta_{21}\ \eta_{22}\ \eta_{23}\\ .\\ .\\ \eta_{91}\ \eta_{92}\ \eta_{93}\end{bmatrix};\quad Z=\begin{bmatrix}w_1\\ w_2\\ w_3\end{bmatrix} \tag{8}$$

$$\& \sum_{i=1}^{3} w_i = 1 \tag{9}$$

Assumption is using L9 orthogonal array. w_1 is the factor of product yield; w_2 is the factor of shrinkage porosity; w_3 is the factor of filling velocity; η_{jc} is the multi-response S/N ratio in the j^th^ test. η_{ji} is the ith single response S/N ratio for the j^th^ test. w_i is the weighting factor in the i^th^ performance characteristics. The objective function was formulated according to the previous optimisation criteria:

$$\text{Maximize } f(X) = \eta_{Yield}w_1 + \eta_{Porosity}w_2 + \eta_{Velocity}w_3 \tag{10}$$

Where w_1, w_2, w_3 are the weighting factors of S/N ratio for yield, porosity and velocity, respectively.

V. Analysis of Variance (ANOVA)

The purpose of the ANOVA is to investigate which of the process parameters significantly affect the performance characteristics. This is accomplished by separating the total variability of the multi-response S/N ratios, which is measured by the sum of the squared deviations from the total mean of the multi-response S/N ratio, into contributions by each of the process parameters and the error. The five connective parameter symbols can be calculated as Eqs. (11) and (12)

$$SS_p = \sum_{i=1}^{m}\frac{(S\eta_{jc})^2}{t} - \frac{1}{m}\left[\sum_{i=1}^{m}\eta_{ic}\right]^2 \tag{11}$$

$$SS_T = \sum_{i=1}^{m}\eta_{jc}^2 - \frac{1}{m}\left[\sum_{i=1}^{m}\eta_{ic}\right]^2 \tag{12}$$

$$V_P = \frac{SS_P}{D_P}\times 100 \tag{13}$$

$$SS'_P = SS_p - D_pV_e \tag{14}$$

$$P_p = \frac{SS'_P}{SS_T}\times 100 \tag{15}$$

Where m is the number of the tests (m= 9). p represents one of the tested parameters, j is the level number of this parameter p, t is the repetition of each level of the parameter p, and $S\eta_{jc}$ is sum of the multi-response S/N ratio involving this parameter p and level j. The total degree of freedom is $D_T = m-1$, for the tested parameter, $D_p = t-1$, V_p is the variance, SS'_p is the corrected sum of squares and P is the contribution of reach individual factor.

VI. Computational Experiment

Simulation of the mould filling and solidification process required geometrical information for the casting, the gating system and the sand mould. Solid CAD models were created using the Pro-E wildfire 4.0 software of PTC (Parametric Technology Corporation) and converted into PARASOLID (.x_t) file. Then the PARASOLID (.x_t) file directly imported to ProCAST 2009.1 for simulation. Once the meshed geometry is established, the casting process design parameters, then the initial boundary conditions are defined according to the actual experimental condition for doing simulation. The boundary condition should be defined for all simulation experiments. With the ViewCast module the fluid flow in the cavity and solidification during the casting process were analyzed and potential defects were predicted. The ViewCast can only view the fluid flow and temperature field patterns in the cavity during the casting process and predict the potential defects graphically. in order to generate the corresponding simulation result data file according to the specific 3D coordinate in the casting model based on FEM model node number VisualCast module (ProCAST 2009.1) was employed to study to predict the filling velocity and shrinkage porosity numerically.

VII. Result and Discussion

Based on simulation result the value of shrinkage porosity & filling velocity are for different 9 sets of gating system. Casting yield is calculated with eq. (2). Now S/N ratio is calculated for all values of the three performance characteristics with at the help of Eq. (4)-(6). The three combination of weighting factor were selected in this study of multi-response S/N ratio calculated with the help of Eq. (7)-(9). Now to calculate the response of each factor to its individual level was calculated by averaging the S/N ratios of all experiments at each for each factor.

For case 1, the order of the performance characteristics is the product yield ($w_1 = 0.5$), the shrinkage porosity ($w_2 = 0.2$), and the filling velocity ($w_3 = 0.3$). For case 2, the order of the performance characteristics is the product yield ($w_1 = 0.3$), the shrinkage porosity ($w_2 = 0.5$), and the filling velocity ($w_3 = 0.2$).Finally, for case 3, the order of the performance characteristics is the product yield ($w_1 = 0.1$), the shrinkage porosity ($w_2 = 0.2$), and the filling velocity ($w_3 = 0.7$). Figs. 6.1–6.3 show the multi-response S/N ratio for case 1–3, respectively. The multi-response S/N ratio for each level of the gating system parameter is calculated based on Eqs. (7) – (9).

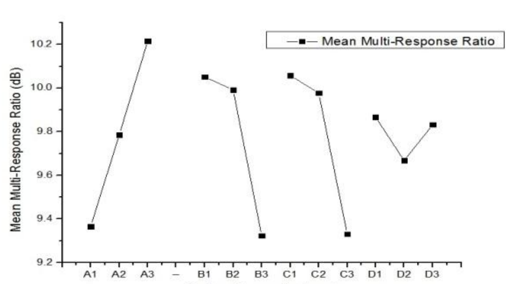

Fig. 2 : Multi-response S/N ratio graph for case 1 ($w_1 = 0.5$, $w_2 = 0.2$, $w_3 = 0.3$)

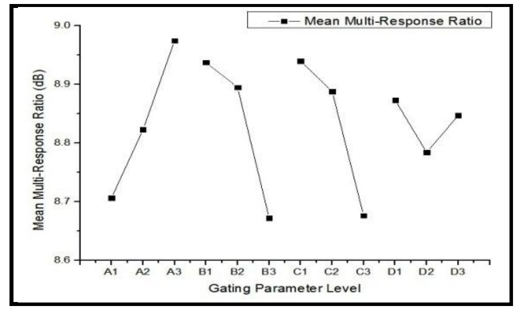

Fig. 3 : Multi-response S/N ratio graph four case 2 ($w_1 = 0.3$, $w_2 = 0.5$, $w_3 = 0.2$)

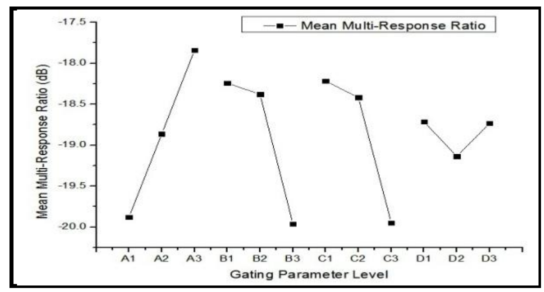

Fig. 4 : Multi-response S/N ratio graph for case 3 ($w_1 = 0.1$, $w_2 = 0.2$, $w_3 = 0.7$)

As shown in previous equations, regardless of the lower-the-better or the higher-the-better performance characteristics, the larger the multi-response S/N ratio the smaller is the variance of performance around the objective value. For case 1, case 2 and case 3 the A3B1C1D1 is the maximum multi-response S/N ratio. The larger ingate height will help to lower the ingate filling velocity characteristic which has largest weighting factor for performance characteristics of all three cases. However, the relative important factor among the gating parameters for the multiple performance characteristics still need to be investigated by using the analysis of variance (ANOVA) method which can conduct the factor contribution more accurately.

VIII. The Factor Contribution With Different Combination of Weighting Factors

The purpose of the ANOVA is to investigate which of the process parameters significantly affect the performance characteristics. This is accomplished by separating the total variability of the multi-response S/N ratios, which is measured by the sum of the squared deviations from the total mean of the multi-response S/N ratio, into contributions by each of the process parameters and the error. First, the total sum of the squared deviations SST from the total mean of the multi-response S/N ratio η_{jc} can be calculated by Eq. (11) – (15). Table (6.7) - (6.9) shows the results of ANOVA for case 1 to case 3. It can be found that the contribution of Ingate height and Ingate width is more than other

Runner factors. The sequence of the four factors affecting the casting quality is the Ingate height, the Ingate width, the Runner height, and the Runner width. For case 1, Case 2 and case 3, the contribution of two Ingate parameters is more than 66%. This shows that ingate parameter make a significant effect on the three case quality objective.

IX. Validation Experiment

The Validation experiment is the final step in verifying the conclusions from the previous round of experimentation. The estimated S/N ratio η_{opt} using the optimal level of gating parameters can be calculated as Eq.16

$$\eta_{opt} = \eta_{tm} + \sum_{j=1}^{n} (\eta_{om} - \eta_{tm}) \qquad (16)$$

Where η_{tm} is total mean of the multi-response S/N ratio, η_{om} is mean of the multi-response S/N ratio at the optimal level, and *n* is the number of the main design parameters that affect the quality characteristics. In confirmation experiment, it is found that the increase in multi-response S/N ratio from the initial gating parameters to the optimal gating parameter is 0.52864 dB. As product Yield has decrease 0.55%, the shrinkage porosity is decreased by 1.19% and filling velocity is decreased by19.14%.For the case 3, the increase of the multi-response S/N ratio from the initial gating parameters to the optimal gating parameters is 0.96734 dB

X. Conclusion

The Taguchi method with multiple performance characteristics has been demonstrated for obtaining a set of optimal gating system parameters based on the defined objectives. The conclusions may be stated; the multiple performance characteristics such as product yield, shrinkage porosity, and filling velocity can be simultaneously considered and improved through this optimisation technique. For case 1 and case 2 and case 3, the A3B1C1D1 is the optimum level with the maximum multi-response S/N ratio. Regardless of the case 1 to case 3, the sequence of the four factors affecting the casting quality is the, the ingate height, the ingate width runner height and the runner width. The ingate height is the most significant factor which influences the casting quality. The optimal parameters for the gating system may be same with different weighting factors from case inside

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Advantage of SWET Technique on Joining Inconel 792 Material

By Suharno, Arif Sugianto, Regnauld Ethan Buntario, Djarot Widagdo, Yuyun Estriyanto & Budi Harjanto
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Abstract - Inconels 792 are nickel-base superalloy material that has high strength and creep resistance at temperature near their melting point. This material is commonly used in aircraft gas turbine (jet) engines, where parts or components are subjected to high temperature and high stress. Not-withstanding the high-temperature capabilities of the alloys, during service the parts are often damaged by hot gas erosion and other types of mechanism. Welding is one of the repair method available nowadays. The application is typically accomplished by Gas Tungsten Arc Welding (GTAW). Unfortunately, however, these superalloys also have limited ductilities at elevated temperatures, and are consequently subject to cracking due to differential thermal strains in some temperature ranges, a phenomenon termed "strain-age" cracking. The solution proposed is Superalloy Welding at Elevated Temperature (SWET). Elevating temperature on the parts or components that are to be welded probably could reduce the thermal gradient occurred, thus creating a crack-free weldments. Also elevated temperature could reduce the amperage needed to achieve the welding temperature, hence lower electricity and cost are resulted.

Keywords : Inconel, Superalloy, GTAW, SWET.

GJRE-A Classification : FOR Code: 091207

ADVANTAGE OF SWET TECHNIQUE ON JOINING INCONEL 792 MATERIAL

Strictly as per the compliance and regulations of:

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Suharno [α], Arif Sugianto [σ], Regnauld Ethan Buntario [ρ], Djarot Widagdo [Ѡ], Yuyun Estriyanto [¥] & Budi Harjanto [§]

Abstract - Inconels 792 are nickel-base superalloy material that has high strength and creep resistance at temperature near their melting point. This material is commonly used in aircraft gas turbine (jet) engines, where parts or components are subjected to high temperature and high stress. Notwithstanding the high-temperature capabilities of the alloys, during service the parts are often damaged by hot gas erosion and other types of mechanism. Welding is one of the repair method available nowadays. The application is typically accomplished by Gas Tungsten Arc Welding (GTAW). Unfortunately, however, these superalloys also have limited ductilities at elevated temperatures, and are consequently subject to cracking due to differential thermal strains in some temperature ranges, a phenomenon termed "strain-age" cracking. The solution proposed is Superalloy Welding at Elevated Temperature (SWET). Elevating temperature on the parts or components that are to be welded probably could reduce the thermal gradient occurred, thus creating a crack-free weldments. Also elevated temperature could reduce the amperage needed to achieve the welding temperature, hence lower electricity and cost are resulted.

Keywords : Inconel, Superalloy, GTAW, SWET.

I. Introduction

Nickel-base superalloys are extensively used in aircraft gas turbine (jet) engines. These superalloys which have the highest volume of precipitates, typically 40 volume percent or more, exhibit the highest strengths and creep resistances at temperature near their melting points (Flowers, G.E, at al.1998).

These high-volume-fraction gamma prime superalloys are used in articles such as turbine blades and vanes, which operate at high temperature for prolonged periods. Hence, these parts are often damaged by hot gas erosion and other types of mechanisms. However, these superalloy materials are difficult and expensive to manufacture. Therefore, when such parts or components are damaged during engine operation, it is far more desirable to repair rather than replace it. As a result, a variety of repair method have been developed and reported.

Repair of damaged region is commonly accomplished by a welding process. After the damaged area is cleaned, a filler metal is melted and applied to the damaged area. The application is typically accomplished by tungsten inert gas welding, wherein an electric arc is struck between the article and a tungsten electrode, forming a molten pool in the damaged region. But there is a problem with the precipitation hardenable alloys, such as Inconel 792. These materials have the inability to weld with a like material for purposes of repair. Welding initiates high temperatures that have a tendency to cause cracking at the area of the weld site, thereby resulting in destruction of the welded parts. The biggest issue is the creation of differential thermal stresses that lead to strain-age cracking and liquation cracking in the weldment and in adjacent regions of the welded substrate. This cracking is harmful to the performance of the welded parts, and a number of methods have been proposed to overcome the cracking.

In one such approach, the application of Superalloy Welding at Elevated Temperature (SWET) is conducted on the parts. Pre-heating prior to welding is done to a temperature greater than its aging temperature and to maintain that temperature during the welding operation. Generally, the purpose of SWET is to minimize the thermal gradient, thus reducing the residual stress created on the weldment. This article will describe the SWET technique and the advantages of its application. An experiment has been carried out to see the performance of the application and will also be explained.

II. What is SWET

Superalloy, like it has been mentioned before, is a very difficult-to-weld material. SWET is advancement in repairing or welding cast superalloy. The application process is heating the article to elevated temperature and maintaining that temperature prior to welding. In the application of SWET, preheating should be in a temperature greater of its aging temperature. This is to avoid the precipitation phase to commence resulting strengthening of the material. The combination of strengthening and stress produced by the welding can cause cracking (Everett, M.A., 1987)

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Preheating will also reduce thermal gradients due to welding operation. Under rapid heating, the grain boundary phases are unable to dissolve fully into the surrounding matrix and partial dissolution leads to the formation of a low melting point eutectic and melting of the grain boundary region. Local dissolution of grain boundary phase will cause liquation cracking or fissuring. Preheating will also reduce cooling rate, thus producing more ductile metallurgical structure with greater resistance to cracking. For superalloy material, preheating typically carried out ranging from 500°C – 1010°C [Mokadem, S. , 2009).

III. Welding Defect

The major difficulty of welding a superalloy is the occurrence chance of defects on the weldments (Fig.1). Most common defect is the hot cracking. Hot cracking predominantly occurs in the Heat Affected Zone (HAZ). Hot cracking occurs due to the effects of the thermal cycle of welding. Rapid heating and cooling occur in the area adjacent to the weld. Incipient melting can be caused by the welding process. Incipient melting at grain boundaries can lead to reduced ductility and subsequent cracking (Donachie, M.J. & Donachie, S.J., 2002).

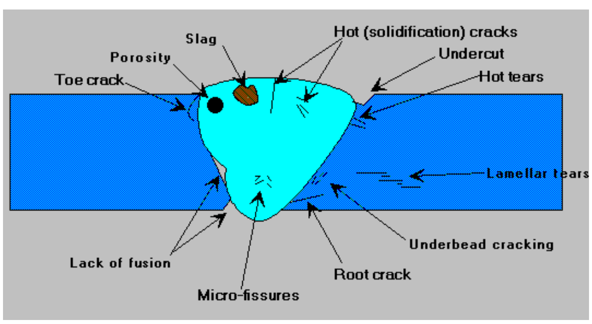

Fig. 1 : Types of defects on weldments (Fontana, F.G., 1987)

Liquation cracking in the HAZ is also another defect that can form due to welding. The liquation or melting occurs because of a reaction between dissolving precipitate and the matrix. When melting is accompanied by sufficient thermal stress, fissuring can form along the HAZ grain boundaries and extend into the fusion zone.

IV. Experiment Procedures

a) *Inconel 792*

Inconel 792 is classified in as-cast nickel-based superalloy which is used for components operating in high temperature, corrosive environment with high working load. This material is typically used for turbine wheel APU that has working temperature ranging from 566 °C – 650 °C and rotating speed at 41.700 RPM (Unknown, 2003). Inconel material exhibit high strength and creep resistance at temperature below their melting points. However, these superalloys also have limited ductility at elevated temperature.

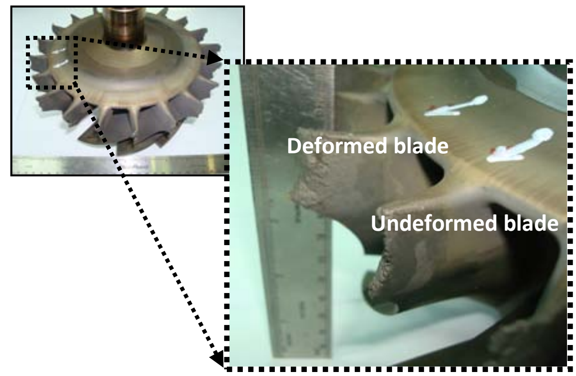

Fig. 2 : Failed and worn out turbine wheel blade tip due to cracking, two samples of defomed and undeformed blade were researched

For the experiment, composition analysis on the specimen is conducted by Energy-Dispersive X-ray analysis (EDX) method.

Tabel 1 : Measured on the spot by EDX system analysis compared to the standard of Inconel 792

Chemical Element	IN-792 (%) Std	Measured on Base
C	0.2	1.7
Ni	60	67.56
Cr	13	10.91
Co	9	11.69
Mo	2	-
Fe	-	-
Al	3.2	2.45
B	0.02	-
Ti	4.2	3.99
Ta	-	-
W	4	-
Zr	0.1	-
Other	2 Nb	1.13 Si
		0.57 S

b) *Preheating*

For this experimental purpose, preheating is applied on temperature 200 °C, 400 °C and 600 °C for 1-2 hours. Preheating the article is performed using a heater and a larger mass holder, as shown in Fig.3.

Fig. 3 : Photograph of larger mass holder covered with heater, part marked as red circle

c) *Repair Welding*

Most common arc welding technique used in many industries is the Gas Tungsten Arc Welding (GTAW). GTAW is a welding process that uses an arc between a tungsten electrode (non-consumable) and the weld pool. The process is used with shielding gas and without the application of pressure. The process may be used with or without the addition of filler metal.

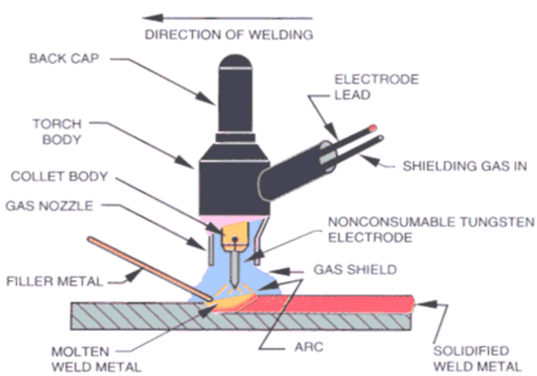

Fig. 4 : Schematic of GTAW Technique (http://www.spectroweldinstitute.com)

GTAW has become indispensable as a tool because of the high-quality welds produced and low equipment costs. GTAW can be used to weld more materials than any other welding process, even exotic and heavier-alloyed metals. Among those materials you can successfully use GTAW for stainless steel, aluminum, nickel, and titanium. This has become the main reasons for selecting GTAW on the repair application (Fig.4).

d) *Advantages of GTAW Technique*

- Produces superior quality of welds, generally free of defects.
- Free of the spatter which occurs with other arc welding processes.
- Can be used with or without filler metal as required for the specific application.
- Allows excellent control of root pass weld penetration.
- Produce inexpensive autogenously welds at high speeds.
- Can use relatively inexpensive power supplies.
- Allows precise control of the welding variables.
- Can be used to weld almost all metals, including dissimilar metal joints.
- Allows the heat source and filler metal additions to be controlled independently.
- Allows for welding in all positions.

e) *Process*

After the article has been mounted on to the larger mass holder and preheated, the welding process can be performed. The GTAW process uses a non-consumable tungsten (or tungsten alloy) electrode held in a torch. Shielding gas is fed through the torch to protect the electrode, molten weld pool, and solidifying weld metal from contamination by the atmosphere (Unknown, 2008).

The electric arc is produced by the passage of current through the conductive, ionized shielding gas. The arc is established between the tip of the electrode and the work. The electricity used for this process is fed from a 65 KVA 3 Phase 63 Ampere 50 Hz Power Electric (Fig.5). Heat generated by the arc melts the base metal. Once the arc and weld pool are established, the torch is moved along area being repaired and the arc progressively melts the faying surfaces. Filler wire, if used, is usually added to the leading edge of the weld pool to fill the repaired area. Cooling of this process is then conducted by still air.

Fig. 5 : GTAW process being performed

V. Repair Results And Discuss

As shown in Fig.6, the welding process has been initiated without any trouble. Visual inspection has been conducted to see any defects on the welded surface and also the HAZ. Observation reveals there is no defect detected yet. Further examination on microstructures should be initiated to see any defects occur in the subsurface.

Fig. 6 : Photographs of welded articles, weldments are marked with red circle

Noticed during the repair accomplishment, the increasing preheating temperature on the parts reduces the amperage needed to achieve the arc of welding. Lower amperage will reduce electricity usage, hence lower cost is needed for welding application. Electricity usage was noted and shown in Table 2.

Table 2 : Electricity usage during welding operation

	Temperature (°C)	Voltage(V)	Amperage (A)
I.200	200	10	17
I.400	400	10	13
I.600	600	10	11

a) Metallographic Examination

Fig. 7 : Photographs of prepared specimen for metallographic examination

Fig.7 shows metallographic practice by cutting, sectioning, mounting, grinding, polishing, and etching was done per ASTM E 3 & E 407. The etching reagent used in this practice was Kalling reagent's No. 2.

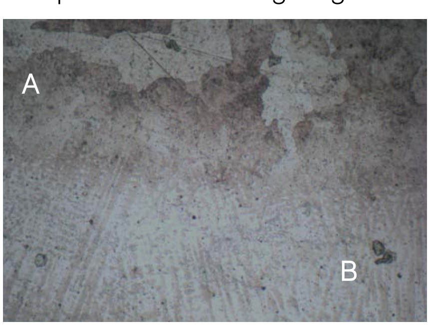

Fig. 8 : Stereo-microscope Photograph of SWET application on 400 °C, A) Base metal and B) Weld metal, etched by Kalling Reagent's no. 2, 100x

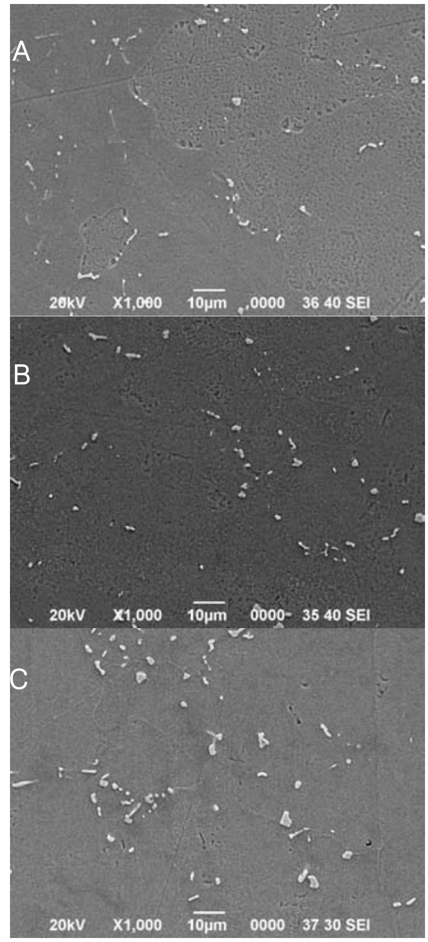

Fig. 9 : Photograph of SEM result welded specimen heated at A) 200 °C, B) 400°C and C) 600°C, Etched by Kalling Reagent's no. 2, 1000x

It is shown on Fig.8, distinct material difference between base metal, Inconel 792, and weld metal, Inconel 625, separated by diffusion line.

Fig.9 shows SEM results after been etched. On the entire specimens, it can be seen carbides forming on the grain boundaries. Gamma-prime precipitates are also available within the gamma matrix. Different color on photographs as an effect of different contrast applied during SEM.

Fig.10 shows photographs of the base metal and weld metal microstructure. Photographs are taken using SEM with 1000x magnification. Fig.10A, 10C and 10E shows base metal with different preheating temperature applied, in orderly 200°C, 400°C, and 600°C. Increased preheating temperature results increasing maximum cooling rate. Hence, softer and smaller grain sizes are formed on the metal. Reducing grain size reduced susceptibility to hot cracking (Donachie, M.J. & Donachie, S.J., 2002). However, there is no distinct difference between the base metal.

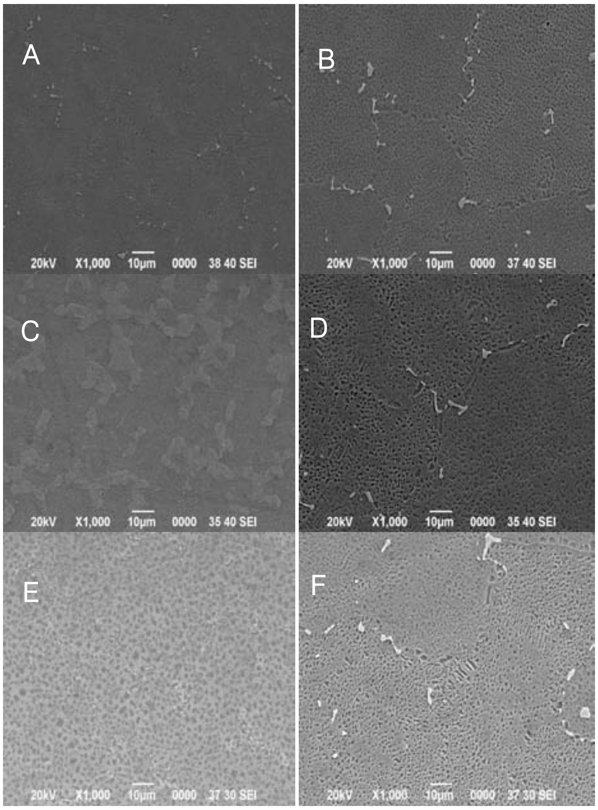

Fig. 10 : Photograph of weld metal and base metal under SEM metallography, 1000X

Fig.10B, 10D and 10F shows no microstructure changes. Because the base metal is far from the welding area and preheating temperature are kept below phase transition temperature, no changes occurred (Unknown, 1992).

As seen on Fig.11, microcracks have been detected on the article that was welded at temperatur 200 °C. Based on the location of the cracks which is on the HAZ area, it is predicted as a liquation cracking (Donachie, M.J. & Donachie, S.J., 2002). Rapid heating on the article creating a huge thermal gradient resulting thermal stress around HAZ area. Another stress applied on the area came from the welding procedure. Welding direction creates transversal tension on the specimen, adding up more stress. The present of a second-phase precipitate can cause increased hardness of the specimen. Increasing hardness and the inability to relieve stress due to welding are a perfect combination to cracking. Increased preheating temperature prior to welding is proposed to reduce thermal gradient and increase maximum cooling rate which enable the article to relieve thermal stress (Haafkens, M.H.,& Matthey, J.H.G., 1982)

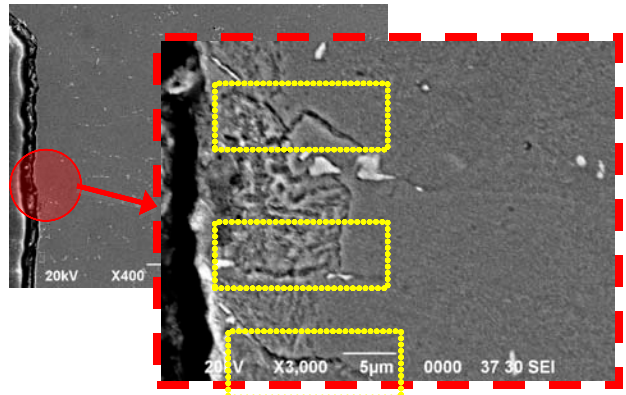

Fig. 11 : Microcracks detected with SEM on the HAZ area on SWET applied article at 200°C, 3000x

b) Microhardness Examination

Inconel 792 is nickel base precipitation-hardening cast superalloy that may be welded in the solution-treated condition because greater ductility of the base metal in the solid solution phase permits stress relaxation during welding. Inconel 792 has 1100-11500C gamma prime solvus temperature in where the solution heat treating at 11200C and the aging heat treating at 845oC is conducted (Donachie, M.J. & Donachie, S.J., 2002). The SWET technique may eliminate strain age cracking at base metal, weld metal, and heat-affected zone upon subsequent heat treatment to develop alloy mechanical properties.

Concerning the result of microhardness distribution shown in Fig. 12, it seems that the preheat temperature 200, 400, 600^{0}C have no significant influence to hardness distribution on HAZ and base metal, except hardness distribution on weld metal

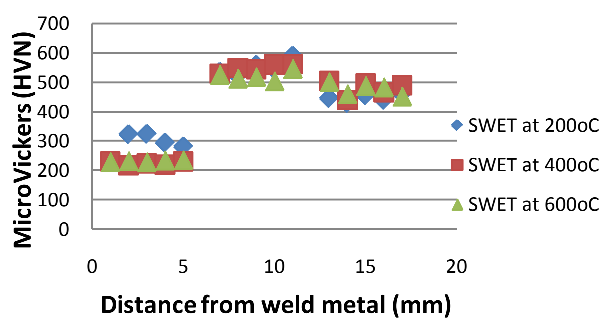

Fig. 12 : Hardness distribution on weld pool, HAZ, and base metal. Name of Machine: Zwick/ Roell Indentec

200^{0}C pre heating somewhat affect the increasing in hardness distribution in weld metal that may be caused by higher cooling rate resulting in smaller grain size in the weld pool. Fig.12 informed that an increase in the pre-weld heat treatment temperature increased the grain size but the hardness decreased, although the hardness of 718 Plus alloys was still greater than that of Inconel 718 (Vishwakarma, K.R., et al., 2005). However, the disadvantage of 200^{0}C preheating is inducing the availability of micro cracks.

c) Advantage of SWET

- Drive away moisture and contaminant from the weld area.
- The slower cooling rate provides an opportunity for hydrogen that may be present to diffuse out harmlessly, reducing the potential for cracking.
- Reducing temperature gradient during welding operation, minimize excessive residual stress, thus reducing chance of cracking.
- More controlled heating and cooling on the material, resulting better microstructure.
- Slow down the cooling rate in the weld metal and base metal, producing a more ductile metallurgical structure with greater resistance to cracking.
- Amperage needed to achieve welding temperature are reduced, welding cost can be minimized.

VI. Conclusions

- This analysis study is based on the evidence of experimental investigation. The following is concluding remarks from this study.
- Inconel 792 is an as-cast nickel-base superalloy and has a difficult-to-weld characteristic
- Welding difficulty is due to its precipitation hardening profile. Welding cause thermal gradient which will induce precipitate formation. Hardening will trap excess stress which leads to cracking.
- Cracking commonly occurs on the HAZ where temperature could increase or decrease rapidly and non-uniform.
- SWET is an application which can solve these difficulties, increasing Inconel-792 part capability to be repaired. Heating article prior to welding will reduce differential of temperature adjacent to the welding area.
- Heating the article prior to and during welding should be done in temperature ranging from 500 °C and 1010 °C.
- Heating will reduce cooling rate, resulting increased ductility and better microstructure.
- Welding technique suitable for SWET application on Inconel 792 is the Gas Tungsten Arc Welding. Because its capability to weld wide range of alloys, low cost equipment, and great quality weldment.
- SWET application not only creating a crack-free weldment, but also reducing welding cost by lowering amperage needed to reach arc of welding.

VII. Acknowledgments

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16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. **Pick a good study spot:** To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. **Think technically:** Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page

- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.
- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.

- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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Segment Draft and Final Research Paper: You have to strictly follow the template of research paper. If it is not done your paper may get rejected.

- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.

- Do not give permission to anyone else to "PROOFREAD" your manuscript.

- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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