# Formulation of Sustainable Eco-Friendly Cutting Fluid for Machining Process Using Statistical Method

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**Abstract:** Sustainable eco-friendly cutting fluid is on high demand in present day machine tool industry because of environmental related issues. This study therefore, highlights the empirical model developed for pH value parameter when additives such as emulsifier, anticorrosive agent, anti-oxidant and biocide were used in the formulation of vegetable oil based cutting fluid with full factorial design. Second order model was developed for the pH value in relation to the formulation parameters. Analysis of variance was used to show the parameters as well as their effects on the pH value model. When the system was optimized, it yielded most desirable optimal values for the formulation process variables as follows: emulsifier = 11.81 %; anticorrosive agent = 3.67 %; antioxidant = 0.76 % and biocide = 0.64 %.

***Keywords***: *Vegetable oil, viscosity, formulation, cutting fluid*

## 1. Introduction

Eco-friendly metalworking fluids from vegetable oils are gaining more importance to avoid health hazard and environmental pollution posed by mineral oil base metalworking fluids during machining processes (Vasu and Reddy, 2011). The increasing environmental problems caused by mineral oil base metalworking fluids are becoming a serious threat to the survival and development of society. The development of cutting fluids was traditionally based on mineral oil because of the good chemical properties and their reasonable prices. However, the two oil crises of 1979 and 1983 have shown that mineral oil is on principle a limited resource. The poor biodegradability of mineral oil and its potential for long-term pollution of the environment and workers health are issues that have prompted the need for alternative to mineral oil based metalworking fluid. This demand for biodegradability materials has opened up the opportunity to consider vegetable oils as sustainable alternative to mineral base oil (Alves & de Oliveira, 2008). Thus, this work presents a new water based metalworking fluid formulation that is able to meet both the performance and environmental requirements for machining processes. The new cutting fluid concept consists of high concentration of water ratio to oil ratio in the proportion of 9:1. In this way, it is possible to have a better heat conductivity and good environmental properties in one fluid. The fatty acid composition of the cottonseed oil sourced from Nigeria was determined at University of Kebaagsaan Malaysia (UKM- UNIPEQ) laboratory as follows: myristic acid 0.1%, palmitic acid 10.31%, stearic acid 0.02% , oleic acid 29.24%, linoleic acid 50.77 % and linolenic acid 7.75%. It indicated that cotton seed oil has approximately 10.43% of unsaturated fat and 87.76% of saturated fat. Other selected properties of the oil that have effect on the formulation of cutting fluid are iodine value 17.40 , pour point -9.0 °C ,flash point 212.5 °C ,

free fatty acid 0.92 (% of palmitic acid ), viscosity at 40°C 31.41 $mm^2/s$ and density 0.92 $g/cm^3$ were all determined at Malaysia Palm Oil Board laboratory, Kuala Lumpur, Malaysia.

## 2. Materials and Experimental Method

### 2.1 Materials

The formulation of oil-in-water emulsion cutting fluid includes the use of other materials and additives. The pH value and quality (hardness / softness) of water are very important parameters in the formulation of emulsion of oil-in-water cutting fluid. The water with pH value of 7.22 (Ong et. al., 2007) was sourced from Kuala Lumpur Water Board. Additives such as emulsifier (A), anticorrosive agent (B), antioxidant (C) and biocide (D) were used in the formulation process

### 2.2 Method

The formulation of oil-in-water process involved the use of design of experiment method (DOE). It is possible to use the factorial design of experiment, when all process factors are known (Montgomery, 2001) and an expected output (response) is fixed to measure the effects of each variable on the process performance. To use the factorial method, lower and upper limits of the variables are fixed and used for the design of mix according to Muniz et al., (2008). Four variables (additives) were examined at two levels ($2^4$ planning) besides the oil and water. Table 1 shows the factors or variables and levels examined in the factorial design.

**Table 1: Factors and levels examined in the factorial design**

| Factor | Symbol | Level | |
|---|---|---|---|
| | | Min - (%) | Max+ (%) |
| Emulsifier | A | 8.0 | 12 |
| Anticorrosive | B | 2.0 | 4.0 |
| Anti-oxidant | C | 0.5 | 1.0 |
| Biocide | D | 0.5 | 1.0 |

This gives a $2^4$ factorial, having sixteen runs. The mixture was stirred using mechanical stirring at speed of 760 rpm for 10 minutes at room temperature of 25°C. The pH values for the sixteen design runs were measured with pH meter. The pH meter was first calibrated with standard solutions. After each measurement, the pH meter probe was cleaned with distilled water before another measurement. The average of the two replications obtained for the responses (pH values) of each run is shown in Table 2.

**Table 2: pH value of $2^4$ full factorial replicated twice with random run order indicated**

| Std | Run | A (%) | B (%) | C (%) | D (%) | pH value |
|---|---|---|---|---|---|---|
| 14 | 1 | 12 | 2 | 1 | 1 | 10.81 |
| 7 | 2 | 8 | 4 | 1 | 0.5 | 11.09 |
| 15 | 3 | 8 | 4 | 1 | 1 | 11.02 |
| 2 | 4 | 12 | 2 | 0.5 | 0.5 | 10.81 |
| 11 | 5 | 8 | 4 | 0.5 | 1 | 11.06 |
| 6 | 6 | 12 | 2 | 1 | 0.5 | 10.78 |
| 3 | 7 | 8 | 4 | 0.5 | 0.5 | 11.17 |
| 5 | 8 | 8 | 2 | 1 | 0.5 | 10.86 |
| 12 | 9 | 12 | 4 | 0.5 | 1 | 11.05 |
| 1 | 10 | 8 | 2 | 0.5 | 0.5 | 10.91 |
| 4 | 11 | 12 | 4 | 0.5 | 0.5 | 11.04 |
| 13 | 12 | 8 | 2 | 1 | 1 | 10.86 |
| 10 | 13 | 12 | 2 | 0.5 | 1 | 10.8 |
| 8 | 14 | 12 | 4 | 1 | 0.5 | 11.02 |
| 16 | 15 | 12 | 4 | 1 | 1 | 11.04 |
| 9 | 16 | 8 | 2 | 0.5 | 1 | 10.83 |

## 3 Results and Discussion

After obtaining the pH value for all the experimental runs, the data obtained were analyzed statistically using version 6 of DOE® software. The software used for the analysis employs a second degree polynomial, approximated by equation 1, to predict the response, Y, which includes all factors as well as the most effectual way the factors interact. The prediction equation is given as

$$Y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_{ij} x_i x_j \qquad (1)$$

where $\beta_0$, $\beta_i$ and $\beta_{ij}$ are constants; $x_i$ represents independent variables and $x_{ij}$ denotes the interactions thereof (Montgomery, 2009). The statistics shown in Table 3 were obtained on performing analysis of variance (ANOVA) on the data obtained.

**Table 3: Analysis of variance (ANOVA) for the model.**

| Source | SS | DOF | MS | F - Value | Prob>F |
|---|---|---|---|---|---|
| Model | 0.227 | 4 | 0.057 | 53.04 | < 0.000 |
| A | 0.013 | 1 | 0.013 | 11.83 | 0.006 |
| B | 0.209 | 1 | 0.209 | 195.63 | < 0.000 |
| C | 0.002 | 1 | 0.002 | 2.11 | 0.174 |
| D | 0.003 | 1 | 0.003 | 2.58 | 0.137 |
| Residual | 0.012 | 11 | 0.001 | | |
| Cor Total | 0.239 | 15 | | | |

The analysis yielded a "Pred R-Squared" of 0.8957, which is in reasonable agreement with the "Adj R-Squared" of 0.9328. The Model F-value of 53.04 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. On analysis of the data, a prediction response equation was obtained as shown in Equation 2.

$$pH = 10.95 - 0.028 * A + 0.11 * B - 0.012 * C - 0.013 * D \quad (2)$$

The statistical values in Table 4 are generated for $R^2$, adj. $R^2$, pred.$R^2$ and adequate precision. The statistical check for this model reveals that the model is adeqaute, specifically, 93.28 % of the observed variability in the reduction pH model can be explained by the model terms in Table 3.

**Table 4: Statistical value**

| Staustic | value |
|---|---|
| R-Squared | 0.9507 |
| Adj R-Squared | 0.9328 |
| Pred R-Squared | 0.8957 |
| Adeq Precision | 18.3211 |

Figure 1 shows the contour plot showing the effect of emulsifier and anticorrosion terms on the pH value. It can be deduced from the plot that when the emulsifier level is high and the level of anticorrosive agent is low, the pH value becomes low. Conversely, when the level of anticorrosive agent increases with decrease in emulsifier, there is an increase in pH value. Therefore, this shows that the purpose of anticorrosive agent in the formulation of cutting fluid to regulate pH value is justified. When steel alloy is used in machining process, the lower the pH value of the cutting fluid, the higher is the tendency for corrosion.

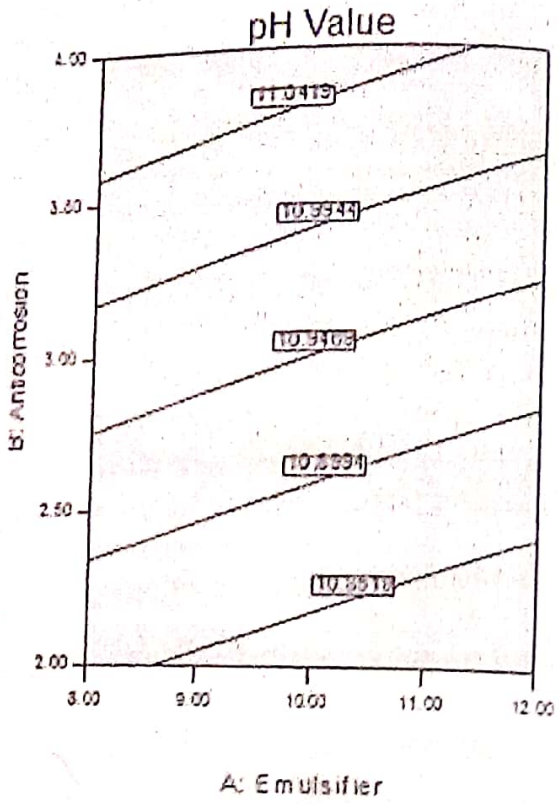


Fig.1: Contour plot showing the combined effect of emulsifier and anticorrosion on pH model

When the system was optimized, it yielded most desirable optimal values for the formulation process variables as follows: emulsifier = 11.81 %; anticorrosion = 3.67 %; antioxidant = 0.76 % and biocide = 0.64 %. The optimized pH value of 11.00 obtained, based on the desirable function was validated with an experiment and a pH value of 10.98 obtained. The viscosity and corrosion level of oil-in-water emulsion cutting fluid with pH value of 10.98 were determined. ASTM 445D method was used to determine the viscosity of the cutting fluid and was found to be 2, while the corrosion level was found using the method decribed by Alves & de Oliveira (2006), and was found to be corrosion resistant.

## 4. Conclusion

Statistical method has been used to predict the pH value of oil-in-water emulsion cutting fluid formulation. Investigation of the properties of oil helped in the determination of the appropriate additives. The optimization by desirability function has been performed to obtain the optimum pH value conditions for the formulation of oil-in-water emulsion cutting fluid. The following conclusions can be drawn in the light of our analysis.

1. The two variables (emulsifier and anticorrosion) have direct effect on the pH value of the formulated oil-in-water emulsion cutting fluid.
2. The data obtained from the experiments are sufficient to build other prediction models because the adjusted $R^2$ is as high as 93.28%.
3. This study also shows that the formulated oil-in-water emulsion cutting fluid is both corrosion resistance and environmentally friendly.

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# Local Content and Capacity Development In Nigeria: Prospects And Gains In Automotive Industries

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**ABSTRACT:** Automotive Assembly Plants were cited in Nigeria since 1959 as a deliberate effort to develop local contents. This would lead not in small measure to capacity building and capability to develop and manufacture automotive parts. In addition, to have economic independence which will replace the comatose economy. The result of this was to lead to gainful employment and strengthen our local currency. For over 40 years of establishment of the auto industries, it is sad to say that the local content input is far below average. This is not unconnected with the decadence of infrastructure in Nigeria and government inability to regulate the influx of foreign parts through our borders using the Import Deletion Programme (IDP). Nigeria is blessed with abundant mineral resources that can be converted to useful materials; unfortunately none of them is developed locally for exports. Record had it that Nigeria is the highest producer of Columbite (located at northern zone of Nigeria) for making aeroplane engine, so also is petroleum products. Having these materials in the country, and the government still prefers imported products of the same materials instead of developing ours will make it impossible for local content to be developed. This has been our attitudes through the years since independence. This paper tries to review the benefits of local content development and the holistic approach required to achieve this in a developing economy such as Nigeria.

*Keywords: automotive industries, local content, capacity and capabilities, auto components.*

## 1.0 INTRODUCTION

Local content is the acronyms given to parts, components, human resources, services or materials adaptive to a locality for wealth generation. Further still, it can be defined as the quantum of composite value added to or created in a nation's economy by a systematic development of capacity and capability through the deliberate utilization of a nation's human, material, resources and services, (Odujirin and Adefulu,1972). Local content development is intended to boost indigenous technology for the production of parts as replacement for foreign goods and services at lower cost.

Imported goods normally attract additional costs that put such goods out of reach of the end users. Such cost includes service cost, packaging cost, freight or transportation cost, duty cost, exercise duty, etc. Ordinarily, some of these costs would have been cut down if such product was produced locally using local materials and technology.

Capacity and capability development of indigenous industries will be far out of reach if an enabling environment is not set and no encouragement is offered by the government. A local industry cannot be one off thing; there is need for interdependence and inter-relationship that must exist between organizations to flourish. The finish product of one organization might be the input material for the other to make a product. The development of a product therefore could comprise so many variances that could be difficult to acquire

in a particular locality. Therefore, for organization to make progress in terms of local content development, the basic infrastructures are required to be put in place by the government for startup.

Meanwhile, the Federal government in its own bit has put in place policies and guidelines for the development of local parts but failed to institute control measures for the implementation of such policies, this is coupled with the lack of will of the executioner to do what is right. Several of these executioners have always taken advantages of government's loop holes on proper control to satisfy their quest by importing sub-standard parts into the country, renamed such and tagged them local parts as disguise for local contents development. This paper, therefore likes to review the importance of local content development if well harnessed.

## 2.0 FEDERAL GOVERNMENT LOCAL CONTENT INTEGRATION PROGRAMME.

The first automobile assembly plant was established in 1959 to assemble Bedford trucks from semi-knocked down (SKD) kits by Niger Motors, a department under United African Company (UAC) ltd. (Famakinwa, 2007). This was followed in 1969 when a Suzuki motorcycle assembly plant by Boulos Enterprises Ltd. was launched in Oregun, lagos, Honda and Yamaha followed later, (Ugbaja, 2007). In 1986, the Federal Ministry of Industry now, Federal Ministry of Trade and investment introduced a local content integration programme with the goal of driving the industry towards achieving 50% local parts integration by 1990 and possibly 90% within ten years period, (Ugbaja, 2007). This type of programme was earlier introduced in 1971 when Federated Motors and other six passengers motor assembly plants were established which include Peugeot Automobile Nigeria (PAN), Kaduna, Volkswagen of Nigeria (VWON), Lagos, British Leyland, Ibadan, Daimler Benze, Enugu, Fiat, Kano, and Steyr Bauchi. (CADD, 1996). In order to boost local production, five other manufacturers of light commercial assembly plants were established. These are: Mitsubishi, Ilorin, Nissan, Minna, Peugeot Gusau, Isuzu, Maiduguri and Mazda, Umuahia.

The agreement of the federal government with these assembly plants was to carry out a backward integration programme to achieve 100% local content in ten years of establishment. Government established these plants with the hope of reducing foreign exchange expenditure on vehicles, create many downstream industries and acquire technology with the anticipation of creating employment for skilled and unskilled workers, but in more than 40 years of existence, non has achieved up to 30% local content. The only plant that made a concerted effort towards integration of local content into its product was Peugeot Automobile Nigeria limited (PAN), that achieved about 30% local content input. Though what was claimed as local content was not really 100% local content. Some of the local suppliers had collaborations to import the claimed local parts, rebrand and supplied such to the company. Though to an extent, that had provided jobs to some semi-skilled workers, but today none of this is in existence.

## 3.0 PERFORMANCE HARACTERISTICS OF AUTOMOTIVE INDUSTRIES IN NIGERIA

The automotive industry is a vital industry for economic development in a developing country. Only a few other industries cover such a wide range of technology and manufacturing process or use as much raw materials, tools, machinery and equipment like the automotive industry (CADD, 1996). When the assembly plants were established in Nigeria, there was optimal utilization of installed capacity. The total installed assembling capacity grew rapidly during the era of motorcycle assembling from about 60,000 unit in 1969 to 600,000 units per annum on single shift of eight hours per day in 1982 (Ugbaja, 2007), and now, the overall capacity utilization of the automotive industry had dropped to about 10% for vehicle assembly and 30% for vehicle components' manufacture. This was not far from the fact that there was a heavy reliance on foreign inputs which collapsed local markets, among other factors. In spite of this development, the automotive sector accounts for five percent of the country are Gross Domestic Product (GDP) and provide employment to about 10% of the country's workforce. (Okoronkwo, 2012).

### 3.1 Development of Local Content input

During pre-Nigeria independence, reports had it that Nigeria was one of the largest producers of columbite, which can be found in areas that span through Kano, Bauchi, Jos, Markurdi and Lokoja. This material is used in alloys for improved strength, production of aeroplane engine and materials with super conductive properties (www.mineralszone.com, 2013), but till date, this material has not been commercialized for monetary gains.

In an attempt to comply with the Federal Government Guideline on the development of local parts input, Peugeot Automobile Nigeria ltd. (PAN) made attempts and achieved about 30% local contents input on some of its old generation vehicles like the 504 and 505 series between 1974 to 1998. Such local contents include: the central console, seat upholstery, paints, GRP bumpers and boot deflector by Styre Bauchi, windscreen and rear screen by ISO Glass and TSG Ibadan, battery by Exide, Ibadan, fly wheel, floor carpet by Nasco, Jos and under hood sealant. This was a welcome progress and a step towards the right direction since it generated employment opportunities and also developing the local companies involved in the supply of the spare parts. If this effort had continued, more local industries such as plastic and rubber transformation, casting and heat-treatment industries would have sprung up in local content development to expedite actions. However, the progress was hindered by lack of infrastructural development, high level of taste of Nigerians for imported goods in preference to locally made goods, low level of technological development and high exchange rate. The local companies could not cope with these problems which led to the extinct of Peugeot 504 and 505 series and other models of locally assembled vehicles. This has caused most of the local content industries to fold up and threw many people out of job. In place of this, Nigeria is now being turned into a dumping ground where different makes of dead automobiles (Used vehicles) are dumped

### 3.2 Benefits of the Auto-Industries to the Nation

The Automotive industry is one of the largest employers of labour. At installed capacity of 108,000 cars, 50,000 trucks, 10,000 tractors and 15,000 three wheeled vehicles per annum (Famakinwa, 2007), the industry is more likely to employ more than 11,000 workforces comprising skilled to unskilled workers (Akmal, et al, 2007). Take for instance, the number of employees that will be involved in a spectrum of business ranging from research, design, development, testing, stamping, casting, machining and assembly to marketing, paints and sealants, rubber and plastics, tyres, glasses, electrical cables and harnesses, distribution and after sales services. (Akmal, et al, 2007). The local contents developers will also take their turns and this will greatly improve the economy of the nation. In the last 10 years, more than 90% of vehicular requirement of the Nigerian economy are imported and more than 90% of the imported vehicles are used ones. (Famakinwa, 2007). Some other benefits to be derived in this industry include:

- ✓ Accelerated Technological development in Nigeria
- ✓ Promotion of local components manufacture and use of local raw materials
- ✓ Promotion of exchange earnings through regional and sub-regional exports
- ✓ Conservation of foreign exchange reserves.

## 4.0 ESTABLISHMENT OF CADD

Centre for Automotive Design and Development (CADD) is a Research organization established by decree 107 of 1992 by Federal government though, currently being merged with the National Automotive Council (NAC), (Onochie, and Hassan, 2012). The Centre was established to promote and encourage local content development through its activities in the design and development of low cost vehicles using local contents, and its objectives are:

- ✓ Design, develop and test low cost vehicle prototypes
- ✓ Provide technical support services to the engineering sector
- ✓ Liaise with the association of Local Content Manufacturers of Nigeria (ALCMAN) and the Nigerian Automobile Manufacturers Association (NAMA) to ensure that the existing capabilities are fully utilized.
- ✓ Draft and recommend standards for the Automobile Industries
- ✓ Coordinate the research and development activities of ALCMAN, NAMA and existing research Centres.

CADD has researched and produced six vehicles. Four 4-wheeled vehicles tagged CADD Mark I, Mark II, Mark II Copy and CADD Hardtop; and two 3-wheeled vehicles (Tricycle), one commuter and one pick up, as shown in Appendix A. The local content inputs on the Mark I, Mark II, and Mark II copy vehicles are 52% and 62% respectively; while the local content inputs for the CADD Hardtop is 70%. The local content inputs on the tricycle stood at 75%. Coupled with this, the Centre has also produced a 4-stroke engine block and other automotive components like crankshaft, top cylinder cover, brake drum, chassis frame and its components, Front and rear axle, splash guide, tricycle rims and other components. Recently, three other engine blocks have been produced. Currently,

efforts are on to change the front axle beam of the Mark II series to an independent suspension system for better traction, control and comfort of passengers on rough roads.

In the course of the research and development programme, CADD had over 200 local content companies to patronize, this cut across the six geopolitical zones of Nigeria. The Directory of this is fully compiled and can be found in the Centre.

The above facts are pointers to the fact that if this work fully comes on stream, it is going to open front for the economic development of Nigeria, create jobs, generate wealth and replace the heavy dependence on oil and gas.

## 5.0 IMPORT DELETION PROGRAMME

To develop a local content programme in Nigeria, the government needs to take an holistic approach with full determination to protect the local industries and auto research organizations. This can be done via the introduction of Local Material Content Policy (LMCP) to promote the local contents and encouraging the automotive industries to aim at achieving 75% local parts content. Grants as rewards should also be given to any company who has attained at least 60% local content inputs in their products to assist such company develop further. The government should also control and work on Import Deletion Programme (IDP) to ban automotive accessories and parts that have been developed locally, in fact, the IDP should be made mandatory with a strong control measure to be administered by CADD/NAC.

On the Nigerian roads, there are different vehicular models plying the roads, those fit and unfit for our road terrain. Among these several fleets, government can institute a policy to cut down the number of imported models to either 3 or 4 types, this will help the indigenous industries to grow and equally assist CADD and other regulated bodies to carry out their objective functions accordingly.

In our ports and borders, government already has in place a protection policy using both tariff and non-tariff measures, but a lot of misfit elements are sabotaging government efforts with the passage of banned items into the country which is one of the reasons why Tokunbo or Belgium (fairly used) vehicles have flooded our market. The only product that we have not started seeing as Tokunbo on our roads now is the Tricycle, but very soon, this will join the train, except an urgent intervention is applied to reverse this trend, this means, to promote and develop the auto industry, a proper control and stiffer measures need to be put in place by the government.

## 6. CONCLUSION

Big prospects await Nigerians in the auto industry if the opportunity in this sector is fully harnessed by developing our local content input. This will equally stir up the interest to resuscitate work on the Ajaokuta project. Imaging the number of work force to be employed in this organization. But the facts remain that, a nation does not need to have 100% local content to develop its own vehicle. All that is required is discipline, control and focus.

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