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AN AMALGAMATED STUDY OF FAILURE RATE AND FRACTIONAL FACTORIAL DESIGNS WITH MINIMUM ABERRATION IN AGRICULTURAL EXPERIMENTS

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ABSTRACT

In the agricultural experiments, many experiments involve the large number of factors or blocks which may be studied simultaneously. In such situation fractional factorial designs are useful because it allows to determining the "vital few" significant factors with aim to abate random error effect. In the present investigation, the way to overcome from the problem of damage block is studied with the conjunction of advance methodology of fractional factorial designs with minimum aberration.

KEYWORDS: Reliability, Failure Rate, Hazard Rate Etc

INTRODUCTION

The essence of economic growth of a country is its agricultural and industrial development. To match with the modernism gives birth to new technologies which automatically boost up the performance, suitability and cost-effectiveness of agricultural as well as industrial products. The rapid growth and development in these sectors made the consumer more rational. Now need of the time is maximum satisfaction at minimum cost. That's why these sectors are bound to provide a sense in all perspective to consumer's that there be the best in all perspectives. However, no agricultural product can be full proof in the presence of varying environmental conditions such as change in temperature, occurrence of random effect and natural disasters. But this does not mean that an agricultural system cannot be made reliable. Better understanding of failures, improved manufacturing techniques, provisions of redundancy, careful planning maintenance and repair at proper stage of operation are some of the approaches which can be used to improve the agricultural productivity as well as its reliability.

To achieve reliability, the detection of failure mode and prevention by prediction in the early stages of new product development using failure modes and effect analysis, fault tree analysis, design review, accelerated life testing etc. are important. But the ultimate quality is how will it performs in the field, that is the collection of the necessary field performance data and their feedback to quality assurance activities should be done. For improving reliability of the agricultural experiments, there are two important goals firstly, identify the important factors that affect the reliability of the product, and secondly levels of the factors that lead to improved reliability. Like other product quality characteristics, the relation between various factors and reliability can also be studied in the light of advance experimental designs. Fractional factorial design took the epochal space in the list of such advance designs because it explores the effects of the individual factor and perhaps their inter-relationship as well [Box and Hunter (1960)].

Almost all probabilistic methods for improving reliability are based on the assumption of constant failure rate. This failure rate can be studied by using exponential distribution because of its random nature. In the other words, if the failure rate is constant, its probability of failure does not change with time. The failure rate is the important variable in the exponential distribution which can be describe the situation wherein the constant hazard rate and so the life testing. In the present study, methodology of calculating hazard rate (or life testing) of the agricultural product,which may be damage block any time because of the random effect,with the conjunction of advance fractional factorial designs with minimum aberration [Box and Hunter (1960), Fries and Hunter (1980), Laxmi at al. (2016)] is studied. It is also shows that the damage block may be replaced by the nearly similar block so that the experimenter cam achieved the efficient response.

METHODOLOGY

Whenever the life testing is the matter of concern within the space of design of experiments, the response is the life or failure time of the product. However, because of the time, cost or other constraints, it may not be observed for some test units. In fact, it may be functioning at the time when the test ends. The end time of the test is called the suspension time for the units that are not failed which is treated as the life time in order to analyses the data[Hitzelberger (1967), Lawlus and Kalbfleisch (1992), Taguchi (1986a,b)]. And if the data contains the large number of factors, and experimenter may need to study in a relative small number of runs, then highly fractionated 2^{k-p} designs are needed which may be consider as the common phenomenon in agricultural experimentation. The common complexity is with response which is affected by a small number of main effects and lower order interaction. In such type of phenomenon fractional factorial designs are very useful because they study only one block and consider near about the similar conditions found in other block in the experimental area which may be used as a standby block if first block is damage because any random effect. For such type of investigation, it is important to study the failure rate of the block under consideration.

For instant, consider the system in which λ is the failure rate of the under process block and λ' is the failure rate of the warm standby block. For such system there are two possible possibilities (Figure 1), firstly when experiment begin both the block are in working condition. After a stage of experimentation under block under consideration is fail with λ rate (this block may or may not be damage permanently) and in other stage standby block is failwith λ' rate and at last stage both the block are damaged. In second possibility both the blocks are working in the last time of the inspection. For such type of situation exponential distribution is appropriate with density fiction $f(t)$ which represented the probability of failure prior to some time t and $F(t)$, the probability in the random trial with the condition that the random variable is not greater than t, and $R(t)$ is reliability function, than the hazard rate $\lambda(t)$ is defined as

$$\lambda(t) = \frac{f(t)}{R(t)}$$

with$f(t) = \lambda$ and $g(t) = \lambda'$.

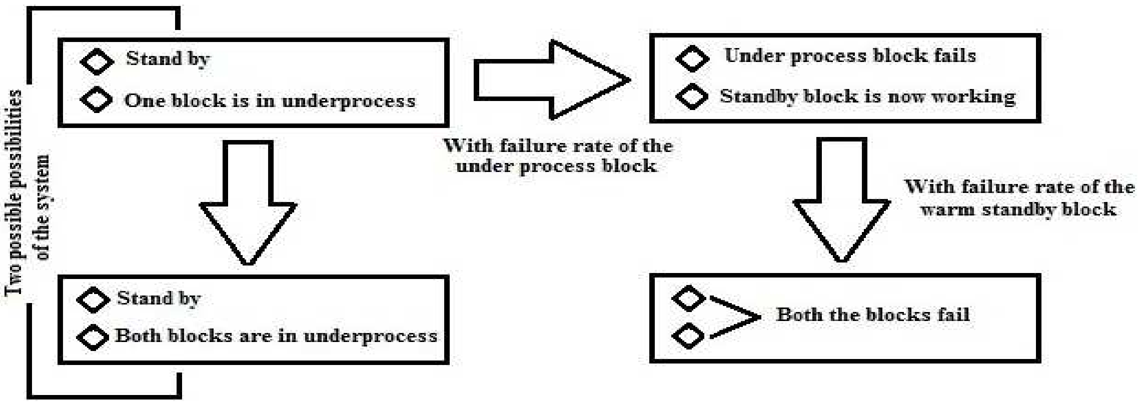

Figure 1: Two Possible Possibilities of the System

When the objective is to study said system under the space of fractional factorial designs, the number of test units and run size rapidly increases as increase in the number of factors which are the part of general phenomenon of fractional factorial design. So it is also important to study above said system with concept of minimum aberrations. For simplify the complexity of the experimentation, consider the five factors (A, B, C, D, E)experiment which need 32 units and all these factors are related to joint effect of the treatments and also parallel in series which shows in Figure 2.

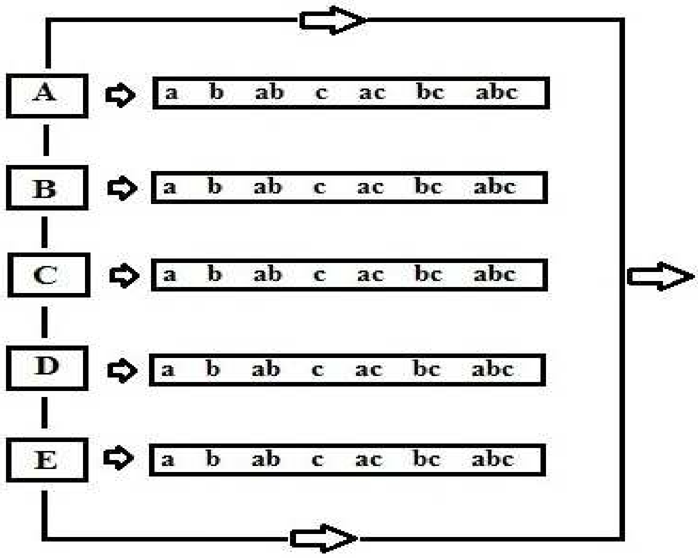

Figure 2: Factors are in Parallel Series

In 2^{5-2} fractional factorial design there are possibilities to have four blocks with 2^3 basic design.

$$I = ACD = BCE$$

$$I = -ACD = BCE$$

$$I = ACD = -BCE$$

$$I = -ACD = -BCE$$

The design 2^{5-2} with factor generators $D = AC$ and $E = BC$ is used and investigated in the experiments. The basic and their treatment combinations are given in the Table 1.

Table 1: Table for Basic & Treatment Combinations

Run	Basic Combination	A	B	C	D=AC	E=BC	Treatment Combination	D= -AC	E=BC	Treatment Combination	Failure Time
1	I	−	−	−	+	+	de	−	+	e	**25 + Maximum Time 30 Days**
2	a	+	−	−	−	+	ae	+	+	ade	
3	b	−	+	−	+	−	bd	−	−	bd	
4	ab	+	+	−	−	−	ab	+	−	abd	
5	c	−	−	+	−	−	c	+	−	cd	
6	ac	+	−	+	+	−	acd	−	−	ac	
7	bc	−	+	+	−	+	bce	+	+	$bcde$	
8	abc	+	+	+	+	+	$abcde$	−	+	$abce$	

The objective is to identify the significant effect that affects the reliability. Two replications are used for each treatment and it ends after one month in which inspection are conducted after two days. If a block under consideration is failed, it means experimenter known the time range or time interval in which failure occurs, but not the exact failure time. It is also seems that this data is totally censored because both the blocks working in same inspection period. Here two different situations (in Table 2 A & B) are studied, first in which two failure rates are closer to each other ($\lambda = 0.05 \& \lambda' = 0.06$), and in second situation they are far to each other ($\lambda = 0.01 \& \lambda' = 0.12$).

Table 2A: When Two Failure Rates are Closer to Each Other

	Inspection Days	Block 1				Block 2			
		f(t)	F(t)	R(t)	λ(t)	f(t)	F(t)	R(t)	λ(t)
Situation 1	2	0.0452	0.0952	0.9048	0.0510	0.0532	0.1131	0.8869	0.0600
	4	0.0409	0.1813	0.8187	0.0500	0.0472	0.2134	0.7866	0.0600
	6	0.0370	0.2592	0.7408	0.0500	0.0419	0.3023	0.6977	0.0600
	8	0.0335	0.3297	0.6703	0.0500	0.0371	0.3812	0.6188	0.0600
	10	0.0303	0.3935	0.6065	0.0500	0.0329	0.4512	0.5488	0.0600
	12	0.0274	0.4512	0.5488	0.0500	0.0292	0.5132	0.4868	0.0600
	14	0.0248	0.5034	0.4966	0.0500	0.0259	0.5683	0.4317	0.0600
	16	0.0225	0.5507	0.4493	0.0500	0.0230	0.6171	0.3829	0.0600
	18	0.0203	0.5934	0.4066	0.0500	0.0204	0.6604	0.3396	0.0600
	20	0.0184	0.6321	0.3679	0.0500	0.0181	0.6988	0.3012	0.0600
	22	0.0166	0.6671	0.3329	0.0500	0.0160	0.7329	0.2671	0.0600
	24	0.0151	0.6988	0.3012	0.0500	0.0142	0.7631	0.2369	0.0600
	26	0.0136	0.7275	0.2725	0.0500	0.0126	0.7899	0.2101	0.0600
	28	0.0123	0.7534	0.2466	0.0500	0.0112	0.8136	0.1864	0.0600
	30	0.0112	0.7769	0.2231	0.0500	0.0099	0.8347	0.1653	0.0600

Table 2B: When Two Failure Rates are Far to Each Other

	Inspection Days	Block 1				Block 2			
		f(t)	F(t)	R(t)	λ(t)	f(t)	F(t)	R(t)	λ(t)
Situation 2	2	0.0532	0.1131	0.8869	0.0600	0.0819	0.1813	0.8187	0.1000
	4	0.0472	0.2134	0.7866	0.0600	0.0670	0.3297	0.6703	0.1000
	6	0.0419	0.3023	0.6977	0.0600	0.0549	0.4512	0.5488	0.1000
	8	0.0371	0.3812	0.6188	0.0600	0.0449	0.5507	0.4493	0.1000
	10	0.0329	0.4512	0.5488	0.0600	0.0368	0.6321	0.3679	0.1000
	12	0.0292	0.5132	0.4868	0.0600	0.0301	0.6988	0.3012	0.1000
	14	0.0259	0.5683	0.4317	0.0600	0.0247	0.7534	0.2466	0.1000
	16	0.0230	0.6171	0.3829	0.0600	0.0202	0.7981	0.2019	0.1000
	18	0.0204	0.6604	0.3396	0.0600	0.0165	0.8347	0.1653	0.1000
	20	0.0181	0.6988	0.3012	0.0600	0.0135	0.8647	0.1353	0.1000
	22	0.0160	0.7329	0.2671	0.0600	0.0111	0.8892	0.1108	0.1000
	24	0.0142	0.7631	0.2369	0.0600	0.0091	0.9093	0.0907	0.1000
	26	0.0126	0.7899	0.2101	0.0600	0.0074	0.9257	0.0743	0.1000
	28	0.0112	0.8136	0.1864	0.0600	0.0061	0.9392	0.0608	0.1000
	30	0.0099	0.8347	0.1653	0.0600	0.0050	0.9502	0.0498	0.1000

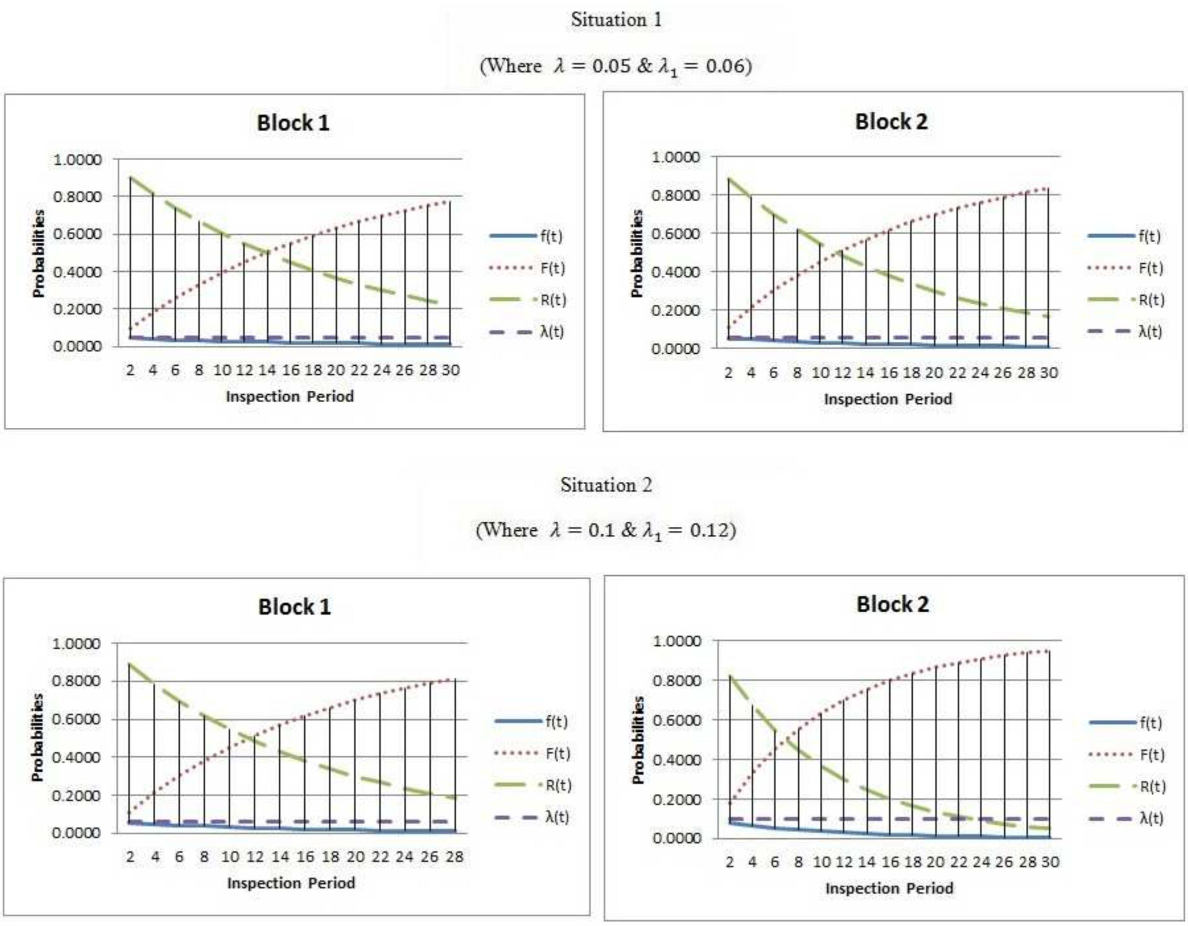

Figure 3: Graphs for Different Probabilities in Different Situations

DISCUSSIONS AND CONCLUSIONS

Fractional factorial are widely known in experiments in fields as diverse as agricultural and industry. The designs concerns with them are among the sevenfold important statistical contribution to the efficient exploration of the effects of several dependent factors on a response. The basal feature of there is that the statistical properties are known in advance with the result that an experimenter can investigate uncertainty. That enables the objective of the experiment to be met with shortest time and most effective use of resources. As in agricultural experimentations, large numbers of factors or blocks are involved at a single time. Consequently, one of two more available possibilities is increase under the random effects which is the common phenomenon in field experiments. Due to these random effects some of the units or blocks under consideration fail to give the adequate response. In such situation, the failure rate of the blocks under consideration is the matter of concern. The objective of this study is to identify the significant effect that affects the reliability of these blocks and replace them with nearly similar blocks. To achieve this motive two different situations are studied and found that different probabilities i.e. density fiction $f(t)$ which represented the probability of failure prior to some time t and $F(t)$, the probability in the random trial with the condition that the random variable is not greater than t, and $R(t)$ is reliability function are having slight variation, because of the experimental error condition which may be considered negligible, and hence the hazard rate $\lambda(t)$. The graphical representation of these probabilities in two different situations also shows that both the blocks are ready to siphon to each other in spite of the fact that there is slight variation in the probabilities.

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