Optimal Replacement or Repair of Aircraft Engine Components Under Maintenance

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Abstract

Preventive maintenance is very important in case of aircraft industries because of very high safety requirement. This paper describes the methodology of optimization using Genetic Algorithm in Mat-Lab for Aircraft industries. Based on the criticality of components the time for maintenance is different for each component in the aircraft. If the system reliability at any point falls below the target reliability than there is a need to take care of some actions against it. As we know, the aircraft engine has the complicated structure with large no of components so this is very complicated to consider each components of the aircraft engine. We generally consider critical components of the aircraft engine.At some point of time if the system reliability falls below the target reliability then we have two options either we have to replace some components or we have to repair some components to achieve the target reliability of the system. An aircraft engine has many components so it becomes very difficult to select which components has to be replaced to achieve the target reliability of the system. Sometime it may be possible to replace only one component or sometime all components need to be replaced. During the preventive maintenance it becomes very important to consider the maintenance cost. If we do the random maintenance, the cost will not be optimal. In this report a maintenance model is suggested to minimize the maintenance cost and to achieve the target reliability of the system. This model is considered for aircraft engine to select the replacement or repair of the components. But this model can be applied to any complicated system.

Keywords: Preventive maintenance, replacement, aircraft engine, reliability

1INTRODUCTION

The engine components are in series and each component has some reliability at any time , if we want to check the system reliability at any time during preventive maintenance, then we have to check whether the system reliability. If it is less than target reliability then we have to go either for different types of maintenance plans for each of the component as given below.

(1) Minimal repair (2) General Repair (3) Repair as good as new

In aircraft engine we have three components (1) compressor (2) Boiler (3) turbine and we have 2 engine as redundant in the aircraft, the aircraft is assumed working if two out of three engines are working and at any point of time we want out target reliability as 0.90, if system reliability is less than target reliability then we have different types of repairs plans asEach plan has different reliability and cost and our aim is to achieve the target reliability with minimum maintenance cost. At instant we check the reliability of components according to structure.

Finding the system reliability as

Engine 1 reliability Rss1=R11.R12.R13, Engine 2 reliability Rss2= R21.R22.R23

Engine 3 reliability Rss3= R31.R32.R33, System reliability R is given by

R=(Rss1.Rss2.Rss3)+ (Rss1.(1-Rss2).Rss3)+ (Rss1.Rss2.(1-Rss3))+ ((1-Rss1).Rss2.Rss3)……………(1)

So we check this system reliability at any instant and if this is greater than target reliability then no need of repair otherwise we have to go for different types of repair plans to achieve target reliability with minimum cost. So this is an optimization problem with objective function as maintenance cost and constraint as system reliability. Genetic Algorithm as optimization tool box is used. It is applied on the aircraft engine components as mentioned earlier. The engine components have many alternatives with different reliability and cost as replacement or repair. There is a need of one component so we have to select one option out of the given options. The objective function in this case is maintenance cost subjected to the target reliability. In this part a model is developed to optimize the alternatives. We cannot do this manually because a large no of combinations are possible. This model can also be used in any types of system. A function of maintenance cost is generated in Mat-Lab as a linear expression of costs of different alternatives and binary decisions variables. The function of reliability is generated in another script of Mat-Lab. To solve this optimization problem a Genetic Algorithm code is generated. This code is run by many no of times to get the result of the problem.

2 LITERATURE REVIEW

Optimal replace repair strategy for servicing products sold with different warranty by Murthy [1], if a product is new and it fails suddenly then we cannot repair this product similarly if the product fails after some reasonable interval then it will not be good to replace that product so in this paper an optimal time is determined up to which we have to choose repair and after this period replacement is opted by minimizing average expected cost. Product warranty and reliability by Murthy [2] in this paper product reliability in contest of product life cycle is discussed, integrated approach needed for warranty reliability management and analysis of various kind of data is done in this paper. Optimal replace repair strategy for servicing products sold with different warranty by Murthy. Analysis of extended warranty policies with different repair options by Chun Su [3] in this paper average expected profit is maximized by selecting the optimal repair options from manufacturers point of view and a conclusion is made that two dimensional non renewing extended warranties are desirable than one dimensional extended warranty policy. .Optimal reliability, warranty and price for new products [4] this paper develops a model to determine the optimal product reliability, price and warranty strategy that achieves the biggest total integrated profit for a general repair product sold under free replacement warranty strategy in a market and look at two scenario for the pricing and warranty of the products.Blichke, [5] discussed about system approach, when the system fails under warranty then how the customers react, in this paper a warranty cost function is generated as a function of warranty duration and they have optimized some performance parameters by maximizing expected manufacturer's profit with decision variables as price and warranty in addition to this. Optimal price and pro rata decisions for combined warranty policies with different repair options [6] in this paper long term average profit as a function of time is calculated and to maximize this profit optimal warranty period for each plan is calculated , the plan having the maximum profit is most optimal and corresponding warranty period is optimal warranty period.

3 PROBLEM FORMULATION

The problem formulated in Mat-Lab and table 1 shows the different reliability and cost of aircraft engine below.

The objective function for maintenance cost in Mat-Lab is given by

```
function z= cost (x)
z=
250000*x(1)+300000*x(2)+200000*x(3)+300000*x(4)+250000*x(5)...

+280000*x(6)+190000*x(7)+350000*x(8)+250000*x(9)+300000*x(10)...

+400000*x(11)+300000*x(12)+290000*x(13)+350000*x(14)+250000*x(15)...
   +400000*x(16)+300000*x(17)+250000*x(18);
```

The engine target relaibilty is given below.

```
function [r, req]= reliabilty(x)
R1=(1-x(1))*(1-x(2))*0.9+0.95*x(1)+0.97*x(2);
R2=(1-x(3))*(1-x(4))*0.92+0.93*x(3)+0.97*x(4);
R3=(1-x(5))*(1-x(6))*0.94+0.92*x(5)+0.99*x(6);
R4=(1-x(7))*(1-x(8))*0.85+0.933*x(7)+0.97*x(8);
R5=(1-x(9))*(1-x(10))*0.93+0.98*x(9)+0.97*x(10);
R6=(1-x(11))*(1-x(12))*0.91+0.966*x(11)+0.98*x(12);
R7=(1-x(13))*(1-x(14))*0.85+0.95*x(13)+0.93*x(14);
R8=(1-x(15))*(1-x(16))*0.96+0.95*x(15)+0.99*x(16);
R9=(1-x(17))*(1-x(18))*0.94+0.97*x(17)+0.95*x(18);
RSS1=R1*R2*R3;
RSS2=R4*R5*R6;
RSS3=R7*R8*R9;
r= [0.95-(RSS1*RSS2*RSS3)+(1-RSS1)*RSS2*RSS3+(1-RSS2)*RSS1*RSS3+...
   (1-RSS3)*RSS1*RSS2,-1+x(1)+x(2),-1+x(3)+x(4),-1+x(5)+x(6),-1+x(7)...
   +x(8),-1+x(9)+x(10),-1+x(11)+x(12),-1+x(13)+x(14),-1+x(15)+x(16),-1+x(17)+x(18)];
req=[];
```

4. METHODOLOGY APPLIED

The methodology applied in this problem is genetic algorithm as a tool for optimization. A code is generated for this as given below. This is an optimization problem with nonlinear constraints so the methodology applied to solve this problem is Genetic Algorithm, now different types of plans have the following details

```
options = gaoptimset('PlotFcns',{@gaplotbestf,@gaplotmaxconstr},'Display','iter');
IntCon = [1,2,3,4,5,6,8,7,9,10,11,12,13,14,15,16,17,18];
[x,fval] = ga(@cost,18,[],[],[],[],[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 ]...
,[1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1],@reliabilty,IntCon,options);
```

Z=(c11.x11+c12.x12+c13.x13+c21.x21+c22.x22+c23.x23+c31.x31+c32.x32+c33.x33)

Subjected to reliability

R=(Rss1.Rss2.Rss3)+ (Rss1.(1-Rss2).Rss3)+ (Rss1.Rss2.(1-Rss3))+ ((1-Rss1).Rss2.Rss3)

Using this code we can get the result of the optimization. The graph in figure 3 showing the different maintenance cost varies with iteration.

Table 1: Reliability and cost for different repair plans

Reliability and cost for engine 1	Minimal Repair r11=0.95 c11=250000	General Repair r12=0.956 c12=300000	Repair as good as new r13=0.97 c11=350000
Reliability and cost for engine 2	Minimal Repair R21=0.94 c21=200000	General Repair R22=0.95 c22=250000	Repair as good as new R23=0.96 c23=300000
Reliability and cost for engine 3	Replacement1 R31=0.93 c31=150000	Replacement2 R32=0.94 c32=200000	Replacement3 R33=0.95 c33=250000

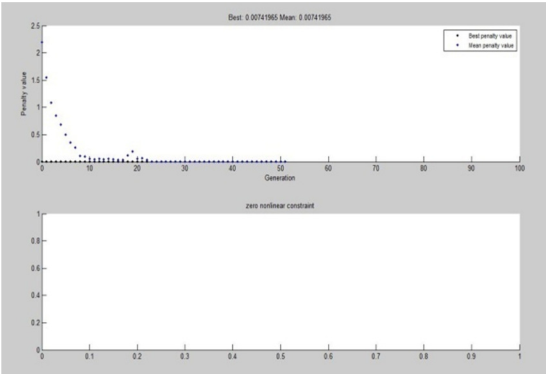

Figure1: Graph for Genetic Algorithm Generation

The result for the given problem is given below.
For Engine 1 component 1 alternative 2, For Engine 1 component 2 alternative 2, For Engine 1 component 3 alternative 2, For Engine 2 component 1 alternative For Engine 1 component 3 alternative 1, For Engine 1 component 3 alternative 1For Engine 3 component 1 alternative 1, For Engine 3 component 2 alternative For Engine 3 component 3 alternative 2So we need to opt Minimal repair for engine1Minimal, General, Repair as good as new for engine 2Replacement1, Replacement2 for engine

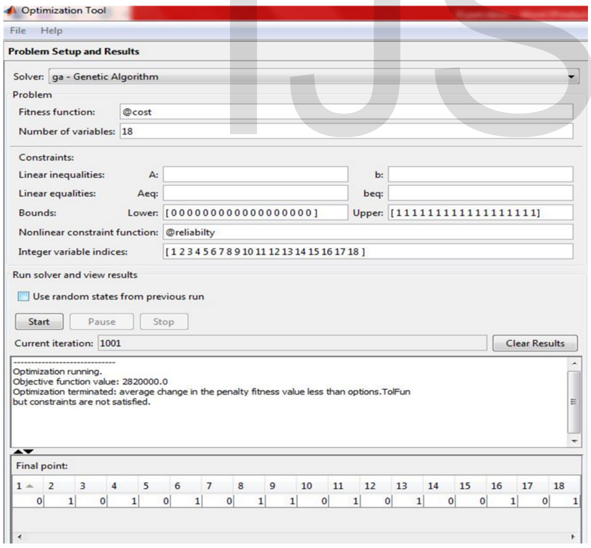

Figure2: Result in Genetic Algorithm

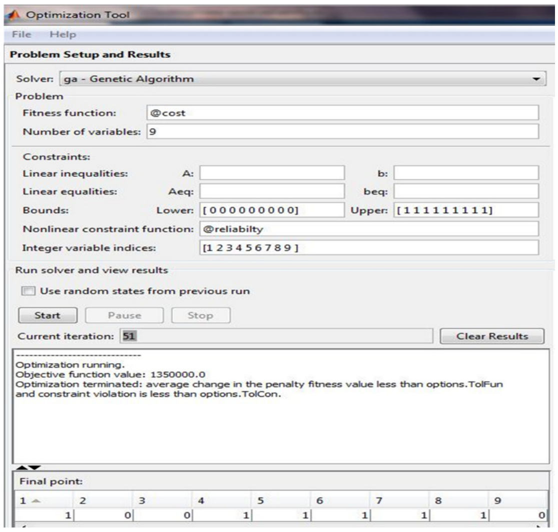

Figure 3: Result using Genetic Algorithm

5 CONCLUSION

We can apply this model in any type of system to achieve the target reliability and to minimize the maintenance cost especially useful in aircraft maintenance where reliability is a very important criterion provided that type of maintenance plans and their reliability is known. We can also replace the product in maintenance if repair is not possible and this repair will have improved reliability and cost so this model is also applicable during design stage with known target reliability. This model is applicable for complicated system with many subsystem and many components in each subsystem. This model is solved using Genetic Algorithm which gives small error so we can use some other module to minimize this error. This model can be utilized in any type of system where we want to achieve target reliability and we want to minimize the maintenance cost. This model is simple to use and requires only formulating the problem so it can be applied by a technical person very easily. One more important utility of this model is in reliability allocation, we can use this model as a reliability allocation method.

6 FUTURE WORK

This problem can be solved using some programming language like c or java to get the exact result of the problem. The errors will becomes zero. This is a generic model so we can use this model in any type of system. This method can also be used as a reliability allocation method during the design stage.

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