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Virtual Fatigue Life Prediction of Back Strip Butt Weld Joint under Bending and Torque Load Conditions

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The welding components used in automobile and aerospace industries are subjected to cyclic loading during field utilization. Understanding the behavior of the weld joints under fatigue loading is essential for designing components for optimum performance. This paper presents the study of virtual fatigue life prediction of back strip butt weld joint under bending and torque load conditions by varying weld joint parameters such as plate thickness, root gap and load. Virtual experiments are carried out on all samples by using finite element analysis (FEA) as per the concept of the design of experiment (DOE) approach. The response surface methodology, one of the DOE approaches, is used to obtain the different weld joint parameter combinations. Static structural analysis is performed to obtain the stress distribution in the weld model. Fatigue life is calculated by using the "E" Class S-N curve. The analysis of variance (ANOVA) approach is exploited to evaluate the influence of weld parameters of plate thickness, root gap and load on fatigue life.

Keywords: weld joint, finite element analysis, design of experiment, static analysis, response surface methodology, fatigue life.

1. INTRODUCTION

Welding is an important aspect in the production process of mechanical components used in automobile and aerospace vehicles [1]. The failure in the weld may lead to loss of key components and sometimes even lives. It should be ensured that the weld meets the strength and integrity requirements [2]. The design of welded components for aircraft applications should be optimized for better performance [3]. New welding techniques are used in the production of aerospace components [4, 5]. A weld component can undergo single or multiple applications of loads and may fail if there is repeated application of load [6]. This failure, due to repeated application of load, is known as fatigue failure. In aerospace vehicles, weld components undergo cyclic loading resulting in high stress. The material properties of weld joints are affected due to the heating and cooling cycles during the welding process [7]. Hence one needs to design the weld component with optimized geometry parameters to meet the maximum fatigue life. Many kinds of literature concentrated on simple weld joints like filler and butt welds [8 – 10]. The fatigue life prediction of such joints gave confidence in analyzing more complex joints like back strip butt weld. Finite element analysis is used to predict fatigue life for some of the most complex loading and complex manufactured components pertaining to backing strip full penetration weld joint [11]. The fatigue life of the welded domain depends on the generation of stress, strain and stress intensity factor in the weld area [12, 13]. S-N curve approach is used for fatigue life assessment of the weld component [14].

Sun and Yang [15] applied rough set theory to study the S-N distribution based on Battelle equivalent structural stress. The authors established S-N curves for Titanium alloy welding joints by considering the three stresses such as nominal stress, structural stress and Battelle equivalent structural stress. Due to the correction of thickness and radius factors in the master S-N curve, the decision-making degrees of welding factors are weakened and harmonized in Battelle equivalent structural stress. It was concluded that the master S-N curve plays a key role in welding fatigue prediction. Goes et al [16] analyzed the fatigue life of welded joints subjected to multi-axial loading. The fatigue life of the flange tube circular welded joint was studied. The virtual results were compared with lab results and design codes Eurocode3 and BS7608. Results revealed that fatigue life obtained from FEA is in good correlation with the theoretical calculation. Chattopadhyay et al [17] proposed the method using shell FEM techniques to find out stress concentration and distribution of stress near to weld toe. The authors proved that not only the variability of radius of weld toe but also the accurate selection of weld toe radius affects the initiation of predicted fatigue crack. The shape of the initial fatigue crack and its further growth life were greatly

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influenced by the distributed spots having minimum weld toe radius.

Etube et al. [18] proposed that fracture mechanics plays an important role in the analysis of cracked bodies. Prediction of fatigue crack growth mainly depends on stress intensity factor solution. This technique helps to seek out crack ratio evolution throughout crack propagation. Al-Mukhtar et al. [19] calculated the stress intensity factor (SIF) using FEM and through software FRAC2D during the crack propagation phase. With the help of linear elastic FEA, the butt and cruciform welded joints were analyzed to decide the SIF. The authors established that in the case of mode I, by applying a numerical approach for the cruciform welded joint cracks, specific SIF can be calculated in different loading conditions for the crack propagation. Jodin et al. [20] evaluated the fatigue resistance of welded excavators arm structures. The authors proposed the methods for its service life prediction revealing that the crack from weld root extended to the shoe of arm bore where bending stress is maximum. Neubers approach was used for result analysis. Fatigue tensile test was performed using a servo hydraulic Instron testing machine.

Teng et al. [21] projected a mathematical model to indicate the brunt of the angle of flank, radius of toe weld, plate thickness, plate chamfer angle and residual stress on the lifetime crack initiation of butt weld joint. FEA of butt weld joint provides the native stress and residual stress distributions that help in forecasting Fatigue Crack Initiation (FCI) life through strain life estimation strategies. Results showed that the tensile residual stress has great brunt on the fatigue strength while longitudinal weld residual stress remains unaffected by the change in radius of weld toe and angle of flank. Gill and Singh [22] studied the butt weld joint which is made of IS2062-E250 A grade steel to understand the brunt of stress concentration factors exerted by gas metal arc weld process parameters like the speed of welding and rate of heat input. Results showed that reinforcement height reduces as the speed of welding increases. An increase in the angle of flank, the width of weld bead and input of heat rate increases the reinforcement height. Berto et al. [23] attempted to provide an easy technique to find out the fatigue life of component based on geometrical parameters and all other statistical information. The author's analysis was based on the steel and aluminum weld joints subjected to multi-axial loading. Strain energy established in a team of mean value was is in good correlation with the values derived using bending and tensile loadings at two million cycles.

The studies of Deshmukh et al. [24] clearly highlighted the corresponding fluctuations observed in the fatigue life with change in weld penetrations. It was observed that the lack of penetration allows a natural stress riser from which a crack may propagate. Deshmukh et al. [25] used finite element analysis to predict fatigue life for backing strip full penetration weld joint and compared FEA results with experimental results for axial load condition. Parameters such as plate thickness, root gap and load were considered as input parameters and the fatigue life was considered as a response parameter. The authors concluded that plate thickness is the most important parameter which affects the weld fatigue life.

The work on fatigue life prediction of back strip butt weld joint under bending and torque load conditions is not carried out till now. In this paper, an endeavor is made to predict the fatigue life of the back strip butt weld joint under bending and torque load conditions through finite element simulation. Static structural analysis is performed to predict the stress in the model. Fatigue life is calculated for corresponding stress obtained theoretically by using the E class S-N curve and compared with the literature. Response surface methodology (RSM), one of the designs of experiment (DOE) approaches, is used to decide the number of combination of samples by using input parameters such as plate thickness, root gap and load. The analysis of variance (ANOVA) approach is used to find the influence of plate thickness, root gap and load on the fatigue life.

2. MATERIALS AND METHODS

Response surface methodology (RSM), a DOE technique [25, 26] is applied to decide the number of simulations considering input parameters such as plate thickness, root gap and load to evaluate the response i.e. fatigue life. These input parameters are considered at 5 different levels which are categorized as -2, -1, 0, 1, and 2. Central composite design (CCD), one of the RSM models [27], is used for developing the 20 different simulations as shown in Fig. 1 and the values for different parameters with levels are shown in Table 1 and Table 2 for bending and torque load conditions.

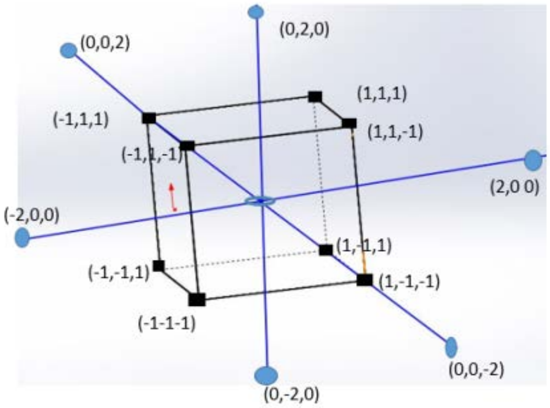

Fig. 1. Central composite design

Table 1. Weld joint parameters and their values at different levels for bending load

Variables	Weld joint parameters	Levels				
		-2	-1	0	1	2
X1	Plate thickness, mm	4	5	6	8	9
X2	Root gap, mm	1.5	2	2.5	3	3.5
X3	Load, kN	0.6	0.7	0.8	0.9	1

Table 2. Weld joint parameters and their values at different levels for torque load

Variables	Weld joint parameters	Levels				
		-2	-1	0	1	2
X1	Plate thickness, mm	4	5	6	8	9
X2	Root gap, mm	1.5	2	2.5	3	3.5
X3	Load, kN	22	32	40.5	62.5	70

Table 3 represents the 20 combinations of models by considering input parameters and response parameters based on the CCD of RSM. Coded values and actual values are presented in Table 3. These 20 models are prepared for applying bending and torsion loads. The steel of E350 grade is considered as the material for the back strip butt weld joint. Material composition, yield stress and ultimate tensile strength are given in Table 4.

2.1. Modeling of back strip butt weld joint

The back strip butt weld joint model is designed via CATIA V5 by using input parameters such as plate thickness, root gap and load. The 20 models are designed as per the combinations mentioned in Table 3. Fig. 2 shows the three-dimensional back strip butt weld joint model designed via CATIA V5.

Finite element analysis is carried out via ANSYS workbench. Static structural analysis is performed to determine the stress in the back strip butt weld joint.

Fig. 3 and Fig. 4 show the boundary conditions applied. On one side, all degrees of freedom are fixed and another side, bending and torsion loads are applied. Shell 281 and Surf 154 elements are used for the discretization process.

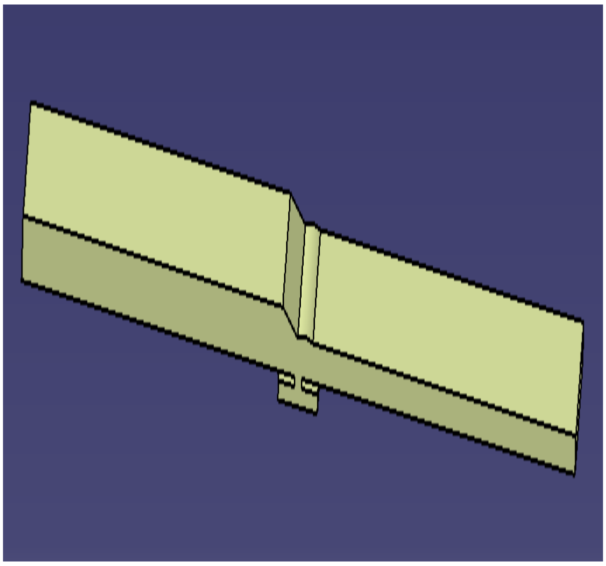

Fig. 2. 3D CATIA V5 model

Table 3. Different combinations of models based on CCD of RSM for bending and torque loads

Run order	Plate thickness, mm		Root gap, mm		Load, kN (bending)		Load, kN (torque)	
	Coded X1	Actual	Coded X2	Actual	Coded X3	Actual	Coded X3	Actual
1	1	8	-1	2	-1	0.7	-1	32
2	1	8	-1	2	1	0.9	1	62.5
3	1	8	1	3	-1	0.7	-1	32
4	1	8	1	3	1	0.9	1	62.5
5	-1	5	-1	2	-1	0.7	-1	32
6	-1	5	-1	2	1	0.9	1	62.5
7	-1	5	1	3	-1	0.7	-1	32
8	-1	5	1	3	1	0.9	1	62.5
9	2	9	0	2.5	0	0.8	0	40.5
10	-2	4	0	2.5	0	0.8	0	40.5
11	0	6	2	3.5	0	0.8	0	40.5
12	0	6	-2	1.5	0	0.8	0	40.5
13	0	6	0	2.5	2	1	2	70
14	0	6	0	2.5	-2	0.6	-2	22
15	0	6	0	2.5	0	0.8	0	40.5
16	0	6	0	2.5	0	0.8	0	40.5
17	0	6	0	2.5	0	0.8	0	40.5
18	0	6	0	2.5	0	0.8	0	40.5
19	0	6	0	2.5	0	0.8	0	40.5
20	0	6	0	2.5	0	0.8	0	40.5

Table 4. Material properties and composition for E350 steel

Grade designation	Chemical composition, %					Yield stress, MPa	Ultimate tensile strength, MPa
	C	Mn	S	P	Si		
E350 (IS2062)	0.20	1.55	0.040	0.040	0.45	350	490

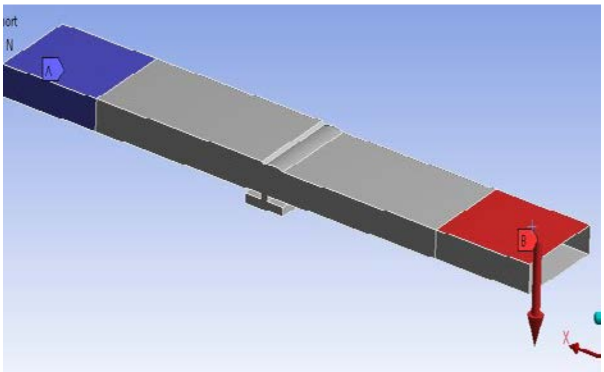

Fig. 3. The boundary condition for bending load

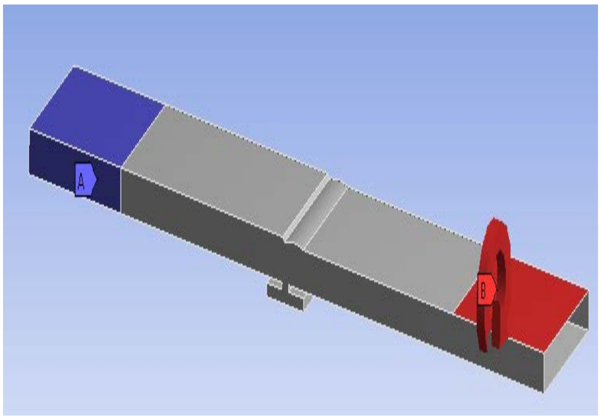

Fig. 4. The boundary condition for torque load

2.2. Validation

Table 5 shows the validation of the present model with literature results [11] for axial load and the error is 6.08 %. It shows the veracity of the present model. Hence it is decided to carry the further analysis with the present models for different combinations using DOE approach.

Table 5. Showing validation of the present model with literature

Plate thickness, mm	Root gap, mm	Load, kN	Fatigue life (present model)	Fatigue life (Deshmukh et al. [11])	Error
6	2.5	40.5	98324	92342	6.08 %

3. RESULTS AND DISCUSSION

3.1. Fatigue life estimation due to bending load

Static structural analysis is performed on all samples to find the strain life of the back strip butt weld joint. Fatigue life is calculated theoretically for the model by using the E class S-N curve, as per BS7608 standards, by the corresponding stress obtained in the ANSYS. Table 6 shows the calculated fatigue life for all the 20 models under the bending load condition. Samples 3, 12 and 14 show the maximum fatigue life for the designed models under bending load.

The Analysis of variance (ANOVA) approach is applied to find the effect of plate thickness, root gap and load on the fatigue life. Table 7 shows the ANOVA results along with a sum of squares.

3.1.1. Regression equation

The regression equation is obtained from the ANOVA analysis to predict the effect of individual parameters on fatigue life. Eq. 1 shows the regression equation for the back strip butt weld joint under bending load condition. In Eq. 1, THK and RG represent the thickness (in mm) and root gap (in mm) respectively. For regression Eq. 1, the corresponding individual parameters such as plate thickness, root gap and load are substituted for individual samples and fatigue life from the regression equation is calculated. The error is calculated between the fatigue life obtained through FEA simulation and regression equation as shown in Table 8. The obtained errors are below 5 which shows the authenticity of the regression equation.

Main effect plots are plotted to find the effects of plate thickness, root gap and load on fatigue life individually. Fig. 5 shows the main effect plot under bending load condition. It is evident from Fig. 5 that there is an increase in fatigue life up to the plate thickness of 6 mm and then fatigue life decreases. For a root gap of 1.5 mm, there is a maximum fatigue life. Between 2.5 mm to 3 mm, it remains constant. Fatigue life decreases as load increases (up to 0.9 kN) but for load 1 kN, there is an increase in fatigue life due to reduced thickness in the model.

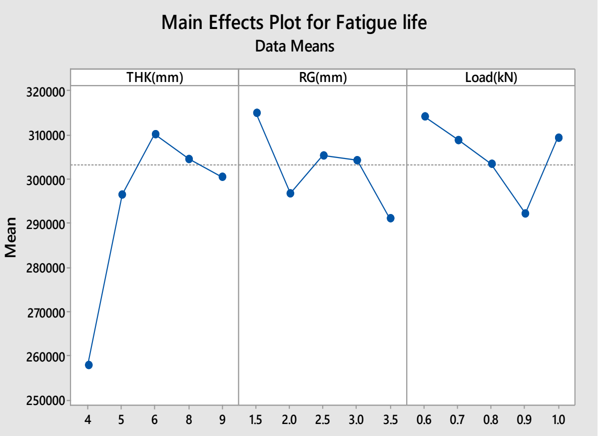

Fig. 5. Main effect plot for bending load condition

Contour plots are obtained to study the effects of interaction between two parameters on fatigue life. Fig. 6, Fig. 7, and Fig. 8 show the contour plots.

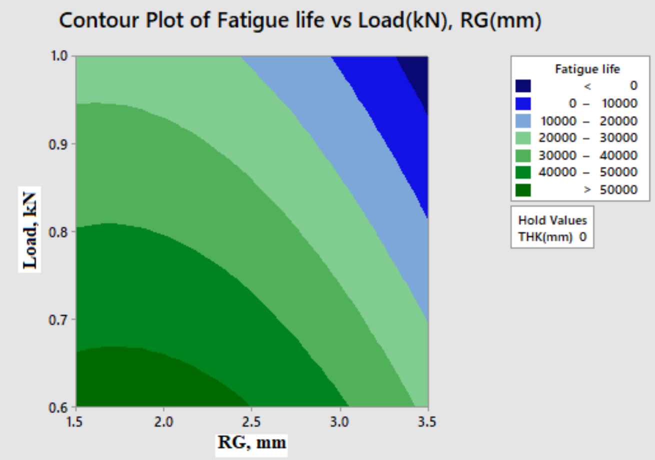

Fig. 6. Effect of load and root gap on fatigue life

Table 6. Results for back strip butt weld joint under bending load

Sl. No.	Thickness (TNK), mm	Root gap (RG), mm	Load, kN	Fatigue life
1	8	2	0.7	301807
2	8	2	0.9	300246
3	8	3	0.7	320409
4	8	3	0.9	296122
5	5	2	0.7	308026
6	5	2	0.9	277295
7	5	3	0.7	305481
8	5	3	0.9	294692
9	9	2.5	0.8	300453
10	4	2.5	0.8	257876
11	6	3.5	0.8	291047
12	6	1.5	0.8	314918
13	6	2.5	1	309307
14	6	2.5	0.6	314048
15	6	2.5	0.8	311884
16	6	2.5	0.8	311884
17	6	2.5	0.8	311884
18	6	2.5	0.8	311884
19	6	2.5	0.8	311884
20	6	2.5	0.8	311884

Table 7. ANOVA results for fatigue life

Source	DF	Adj SS	Adj MS	F-value	P-value
Model	9	3022209830	335801092	3.17	0.044
Linear	3	820589544	273529848	2.58	0.112
THK	1	691251062	691251062	6.52	0.029
RG	1	22130438	22130438	0.21	0.658
Load	1	1883585	1883585	0.02	0.897
Square	3	2143086189	714362063	6.73	0.009
THK×THK	1	2053990060	2053990060	19.36	0.001
RG×RG	1	124830533	124830533	1.18	0.303
Load×load	1	44053	44053	0.00	0.984
2-Way interaction	3	23685157	7895052	0.07	0.972
THK×RG	1	18418518	18418518	0.17	0.686
THK×Load	1	4297807	4297807	0.04	0.845
RG×Load	1	968832	968832	0.01	0.926
Error	10	1060869485	106086949		
Lack-of-fit	5	1060869485	212173897		
Pure error	5	0	0		
Total	19	4083079315			

$$\begin{aligned}\text{Fatique life} &= 61362 + 72711\ \text{THK} + 35267\ \text{RG} - 53698\ \text{Load} - 5871\ \text{THK}\times\text{THK} - \\ &8861\ \text{RG}\times\text{RG} - 4162\ \text{Load}\times\text{Load} + 1969\ \text{THK}\times\text{RG} + 4756\ \text{THK}\times\text{Load} - 6960\ \text{RG}\times\text{Load} \qquad (1)\end{aligned}$$

From Fig. 6, it is obvious that the combination of minimum root gap and minimum load brings maximum fatigue life. From Fig. 7, it is palpable that the combination of root gap (2.5 mm to 3 mm) and thickness (6 mm to 7 mm) fetches maximum fatigue life. From Fig. 8, it is clear that the combination of minimum load and thickness (6 mm to 7 mm) gets maximum fatigue life.

3.1.2. Optimization

Optimization of parameters to get maximum fatigue life is also studied using a response surface optimizer, Peasura, 2015 [28]. Fig. 9 shows the optimized plot. From Fig. 9, it is understood that a combination of the thickness of 6.88 mm, root gap of 2.51 mm and a load of 0.6 kN fetches maximum fatigue life i.e.3258866.

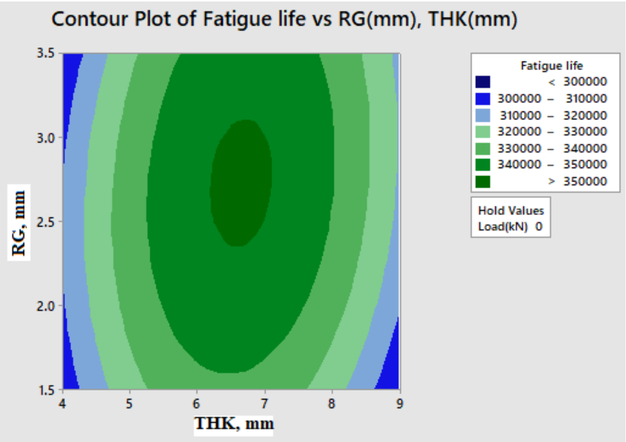

Fig. 7. Effect of root gap and thickness on fatigue life

Table 8. The error between FEA simulation Vs regression equation

Sl.no	Thickness, mm	Root gap, mm	Load, kN	Fatigue life (ANSYS)	Fatigue life (regression equation)	Error, %
1	8	2	0.7	301807	311151.6	3.096
2	8	2	0.9	300246	303905.8	1.218
3	8	3	0.7	320409	312993.6	2.314
4	8	3	0.9	296122	304355.8	2.780
5	5	2	0.7	308026	300186	2.545
6	5	2	0.9	277295	290086.6	4.612
7	5	3	0.7	305481	296121	3.064
8	5	3	0.9	294692	284629.6	3.414
9	9	2.5	0.8	300453	291989.9	2.816
10	4	2.5	0.8	257876	266413.4	3.310
11	6	3.5	0.8	291047	300217	3.150
12	6	1.5	0.8	314918	305801	2.895
13	6	2.5	1	309307	301859.3	2.407
14	6	2.5	0.6	314048	321547.7	2.388
15	6	2.5	0.8	311884	311870	0.0045
16	6	2.5	0.8	311884	311870	0.0045
17	6	2.5	0.8	311884	311870	0.0045
18	6	2.5	0.8	311884	311870	0.0045
19	6	2.5	0.8	311884	311870	0.0045
20	6	2.5	0.8	311884	311870	0.0045

To confirm the fatigue life obtained from the optimization study, FEA simulation is carried out using the optimized parameters to find the fatigue life. The error between these two is found to be 5.47 % and Table 9 shows the same.

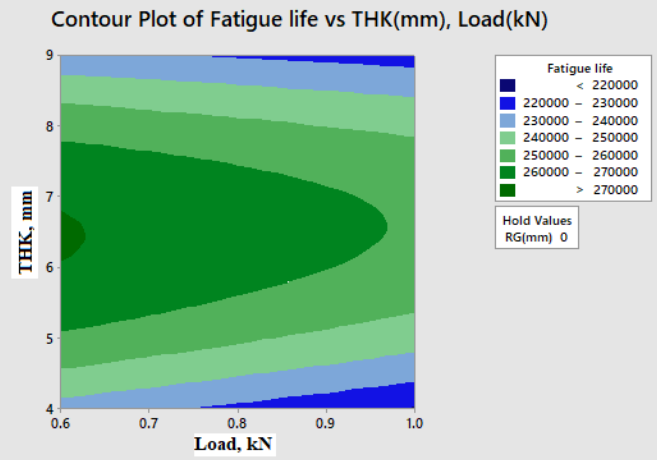

Fig. 8. Effect of thickness and load on fatigue life

Table 9. Results of the optimized model

Thickness, mm	Root gap, mm	Load, kN	Fatigue life (ANSYS)	Fatigue life (optimization)	Error, %
6.8	2.5	0.6	308026.85	325866	5.47

3.2. Fatigue life estimation due to torque load

Torque is applied on all the 20 samples to find the maximum stress via FEA simulation. Corresponding fatigue life is calculated for individual models by using the E class S-N curve. Table 10 shows the fatigue life for all 20 samples of the back strip butt weld joint under torque load condition. Samples 1, 9 and 14 exhibit the maximum fatigue life.

The Analysis of variance (ANOVA) approach is applied to find the effect of plate thickness, root gap and load on fatigue life. Table 11 shows the ANOVA results along with a sum of squares.

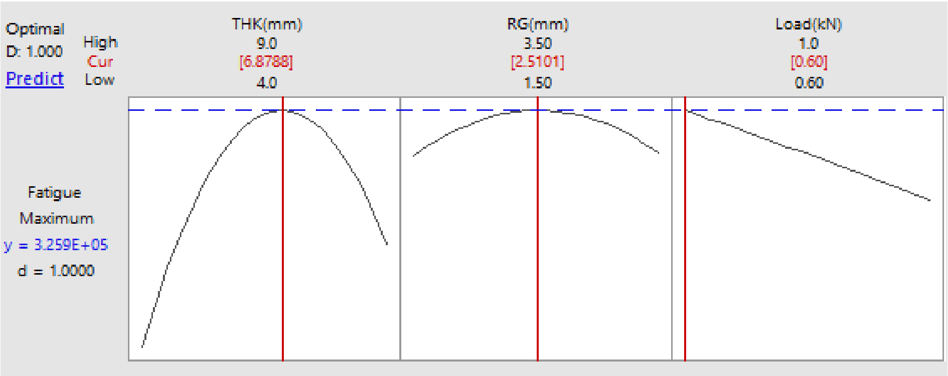

Fig. 9. Response optimization model parameters

Table 10. FEA results for back strip butt weld joint under torque load condition

Sl. No.	Thickness, mm	Root gap, mm	Load, kN	Fatigue life
1	8	2	32	322632.9
2	8	2	62.5	299831.2
3	8	3	32	300246.2
4	8	3	62.5	268057.7
5	5	2	32	306963.7
6	5	2	62.5	295304.6
7	5	3	32	316446.5
8	5	3	62.5	301286
9	9	2.5	40.5	321964.4
10	4	2.5	40.5	308239.9
11	6	3.5	40.5	299003.1
12	6	1.5	40.5	308880
13	6	2.5	70	308026.4
14	6	2.5	22	326899.6
15	6	2.5	40.5	314265.9
16	6	2.5	40.5	314265.9
17	6	2.5	40.5	314265.9
18	6	2.5	40.5	314265.9
19	6	2.5	40.5	314265.9
20	6	2.5	40.5	314265.9

Table 11. ANOVA results for fatigue life

Source	DF	Adj SS	Adj MS	F-value	P-value
Model	9	2659294616	295477180	7.02	0.003
Linear	3	890862560	296954187	7.06	0.008
THK	1	455174785	455174785	10.81	0.008
RG	1	737918661	737918661	17.53	0.002
Load	1	30284378	30284378	0.72	0.416
Square	3	335374471	111791490	2.66	0.106
THK×THK	1	28824461	28824461	0.68	0.427
RG×RG	1	312773178	312773178	7.43	0.021
Load×Load	1	689516	689516	0.02	0.901
2-Way interaction	3	865521147	288507049	6.85	0.009
THK×RG	1	610535197	610535197	14.51	0.003
THK×Load	1	221772268	221772268	5.27	0.045
RG×Load	1	16454366	16454366	0.39	0.546
Error	10	420885945	42088594		
Lack-of-fit	5	420885945	84177189		
Pure error	5	0	0		
Total	19	3080180561			

3.2.1. Regression equation

The regression equation is obtained from ANOVA analysis where the influences of input parameters on fatigue life are studied. Eq. 2 shows the regression equation for the back strip butt weld joint under torque load conditions. In Eq. 2, THK and RG represent the thickness (in mm) and root gap (in mm) respectively. For the Eq. 2, the corresponding input parameters such as plate thickness, root gap and load are substituted for individual samples and fatigue life from the regression equation is calculated. The error is also calculated between the fatigue life obtained through FEA simulation and regression equation as tabulated in Table 12. The obtained errors are below 5 % which shows the genuineness of the regression model.

The main effects plot is obtained to find the effects of plate thickness, root gap and load on fatigue life individually. Fig. 10 shows the main effects plot under torque load conditions.

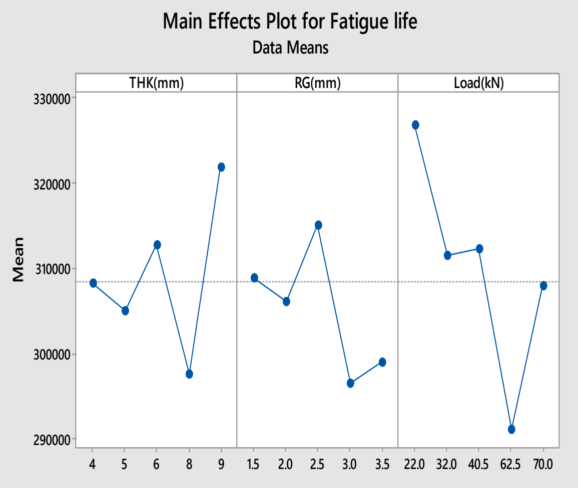

Fig. 10. Main effects plot for torque load condition

$$\text{Fatigue life} = -10509 + 46400\,\text{THK} + 141253\,\text{RG} + 1098\,\text{Load} - 690\,\text{THK}\times\text{THK} - 13928\,\text{RG}\times\text{RG} + 1.18\,\text{Load}\times\text{Load} - 11364\,\text{THK}\times\text{RG} - 217.1\,\text{THK}\times\text{Load} - 180\,\text{RG}\times\text{Load} \quad (2)$$

Table 12. The error between FEA simulation Vs regression equation

Sl. No.	Thickness, mm	Root gap, mm	Load, kN	Fatigue life (ANSYS)	Fatigue life (regression equation)	Error, %
1	8	2	32	322632.9	330747.7	2.515
2	8	2	62.5	299831.2	303685.4	1.285
3	8	3	32	300246.2	305688.7	1.812
4	8	3	62.5	268057.7	273136.4	1.894
5	5	2	32	306963.7	307483.3	0.169
6	5	2	62.5	295304.6	300285.6	1.686
7	5	3	32	316446.5	316516.3	0.022
8	5	3	62.5	301286	303828.6	0.8439
9	9	2.5	40.5	321964.4	310640	3.517
10	4	2.5	40.5	308239.9	309502.8	0.4097
11	6	3.5	40.5	299003.1	296308.7	0.9011
12	6	1.5	40.5	308880	304030.7	1.56996
13	6	2.5	70	308026.4	298633.5	3.049
14	6	2.5	22	326899.6	324843.4	0.6289
15	6	2.5	40.5	314265.9	314097.7	0.0535
16	6	2.5	40.5	314265.9	314097.7	0.0535
17	6	2.5	40.5	314265.9	314097.7	0.0535
18	6	2.5	40.5	314265.9	314097.7	0.0535
19	6	2.5	40.5	314265.9	314097.7	0.0535
20	6	2.5	40.5	314265.9	314097.7	0.0535

Maximum thickness i.e. 9 mm and root gap of 2.5 mm offer maximum fatigue life. From Fig. 10, it is also evident that an increase in load decreases fatigue life except for a maximum load of 70 kN due to the reduced thickness model.

Contour plots help us to study the effects of relations between two parameters on fatigue life. Fig. 11, Fig. 12, and Fig. 13 show the contour plots.

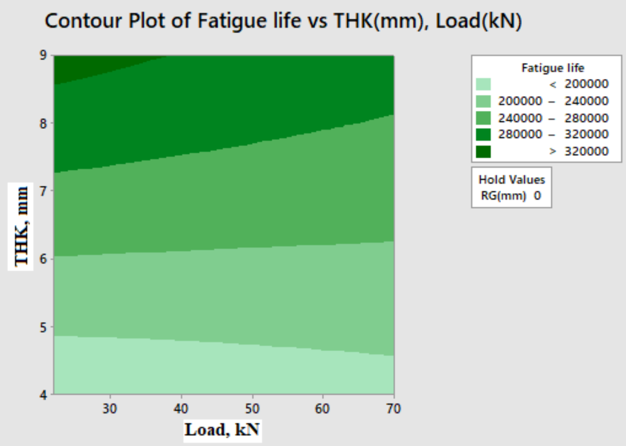

Fig. 11. Effect of thickness and load on fatigue life

From Fig. 11, it is evident that a combination of minimum load and maximum thickness offers maximum fatigue life. Fig. 12 illustrates the relation of root gap and load on fatigue life. It is clear that the influence of root gap is more than that of load on fatigue life. From Fig. 13, it is obvious that a combination of maximum thickness and root gap of 1.5 mm to 2.5 mm gets maximum fatigue life.

3.2.2. Optimization

Optimization of parameters to get maximum fatigue life is also studied using a response surface optimizer.

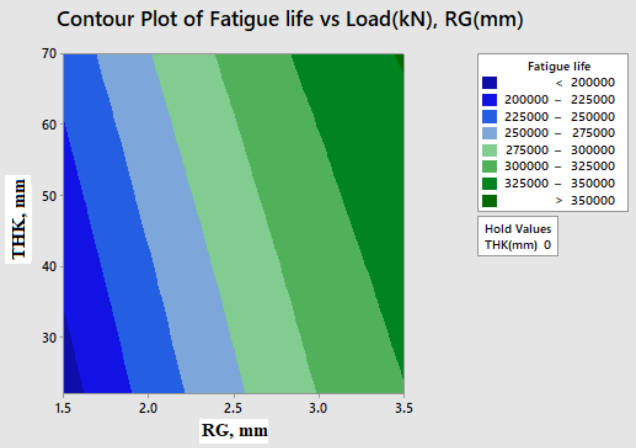

Fig. 12. Effect of load and root gap on fatigue life

Fig. 14 shows the optimized plot indicating maximum fatigue life. From Fig. 14, it is evident that a combination of the thickness of 9 mm, root gap of 1.5 mm and a load of 22 kN presents maximum fatigue life i.e. 3258866.

To validate the fatigue life obtained from the optimization study, FEA simulation is carried out using the optimized parameters to find the fatigue life. The error between these two is found to be 5.47 % and Table 13 shows the same.

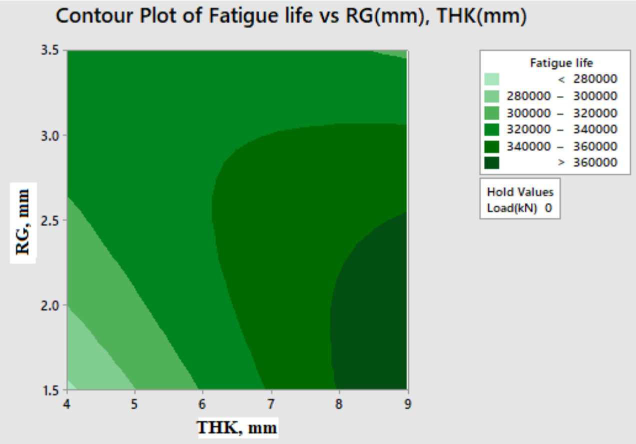

Fig. 13. Effect of root gap and thickness on fatigue life

Table 13. Results of the optimized model

Thickness, mm	Root gap, mm	Load, kN	Fatigue life (ANSYS)	Fatigue life (optimization)	Error, %
9	1.5	22	419636	354129	15.65

4. CONCLUSIONS

In this work, an attempt is made to find the fatigue life of the back strip butt weld joint under bending and torque load conditions by varying input parameters such as plate thickness, root gap and load. DOE approach is used to find the different combinations to perform simulation using FEA. ANOVA is used to find the influence of input parameters on fatigue life. Based on results and discussions, the following conclusions are drawn:

1. ‘Root gap’ and ‘thickness’ have more influence on fatigue life than ‘load’.
2. The increasing thickness helps in increasing fatigue life in the case of torque applications but not completely in the case of bending load applications. In the case of bending load, a model having a thickness around 7 mm achieves maximum fatigue life.
3. Use of root gap of 2 to 2.5 mm yields improved fatigue life in case of both bending and torque load applications.
4. Minimizing the load as much as facilitates improved fatigue life in the case of both bending and torque load applications.

Error analysis between experimental values and regression equation values shows the genuineness of all regression equations and hence these equations help in reducing the computational cost.

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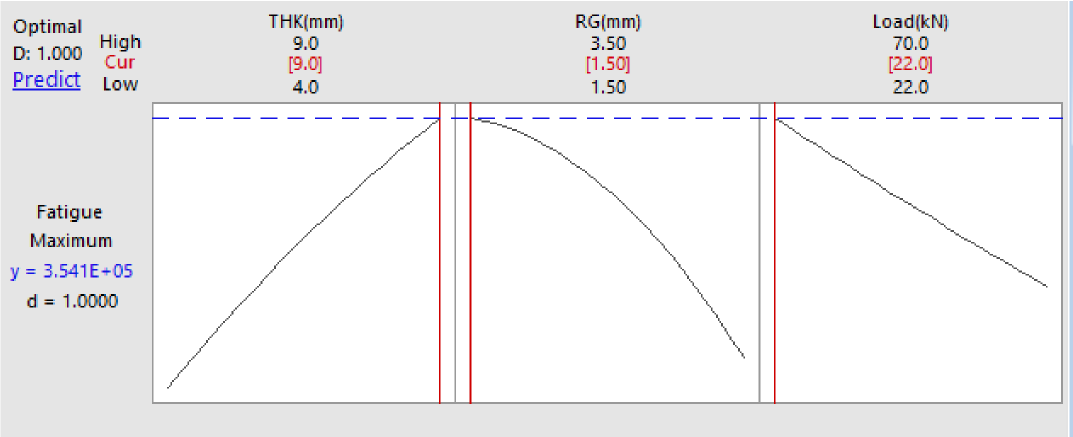

Fig. 14. Response surface optimization plot

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