# A PERIDYNAMIC FATIGUE MODEL BASED ON TWO-PARAMETER REMAINING-LIFE FORMULATION

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## Abstract

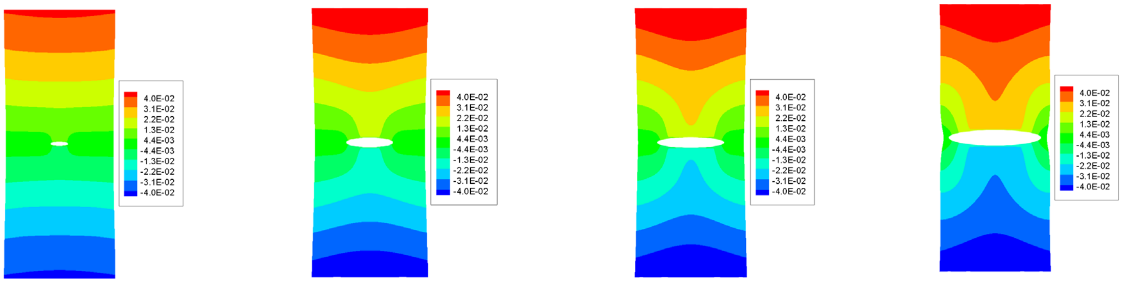
In this paper, a new two-parameter remaining-life concept is introduced in the development of a peridynamic fatigue model. Based on the proposed remaining-life concept, the R-ratio effect is accounted for in the crack growth simulations by applying two independent controlling parameters of cyclic bond strain and maximum cyclic strain in the peridynamic remaining-life governing equation. The validation of the model is performed by assessment of correlation between predicted and experimental crack growth data for 2024-T3 aluminum alloy at various R-ratio loading conditions. The model predicted results show a good agreement with experimental crack growth data.

## 1. Introduction

The remaining-life concept based peridynamic (PD) fatigue model was proposed by Silling and Askari [1]. In this model, the remaining-life equation is formulated as a single parameter of cyclic bond strain as a failure criterion under fatigue loading conditions. Based on the remaining-life concept, Bang et al. [2] and Bang and Ince [3] modified the original PD fatigue model to simulate fatigue crack growth behavior under various loading conditions. However, all of those models showed a limitation of accounting for stress-ratio effect (i.e., R-ratio effect) induced by both monotonic and cyclic loadings. In order to overcome this drawback, a newly formulated remaining-life equation in the PD fatigue model is introduced in this paper, i.e., two-parameter remaining-life equation is formulated as a function of cyclic bond strain and maximum cyclic strain taking into account two-parameter nature of the fatigue damage process. Herein, cyclic bond strain and maximum cyclic strain are considered as two independent PD crack driving force parameters in the new formulation of the PD fatigue damage model. The proposed model provides more efficient and accurate crack growth simulations by accounting for the R-ratio effect induced by different cyclic loading conditions.

## 2. Results

Fatigue crack growth simulations are performed by using the two-parameter remaining-life PD fatigue model for ac2D plate of center cracked tension (CCT) specimen for 2024-T3 aluminum alloy at various loading conditions. The deformation results in the y direction are given under the loading condition of R=0.0/Smax=207MPa as shown in Fig.1. In Fig.1, growing crack length and required number of loading cycles are demonstrated for various load cycles in Fig.1 subfigures a), b), c) and d). By using these crack length vs loading cycle data, the crack growth rate can be determined as a function of the stress intensity factor range in Fig.2a). Herein, the stress intensity factor range, $\Delta K$ is calculated by using the relationship between the PD core cyclic bond strain and stress intensity factor range definition. Fig2.a) shows that crack growth predictions are well matched with the experimental data sets for four different R-ratio loading conditions of R=0.0/207MPa, R=0.33/Smax = 155MPa, R=0.5/Smax=138MPa and R=0.7/Smax=241MPa. In addition, the model predictions are also considered by accounting for R-ratio effects induced by two parts of fatigue loadings (i.e., monotonic and cyclic loadings) in PD fatigue damage simulations. In order to verify the capability of the proposed model for accounting for the R-ratio effect in these simulations, the predictive crack growth master curve is produced as a function of two-parameter driving force, $\Delta\kappa$ for different R-ratio loadings as shown in Fig.2b). The two-parameter driving force, $\Delta\kappa$ is expressed as a function of the two-parameter remaining-life variables of cyclic bond strain and maximum cyclic strain. Fig. 2b) shows that experimental crack growth data at different R-ratios are collapsed on the predictive master curve on the basis of the two-parameter driving force and predicted results are well matched with the experimental crack growth data.



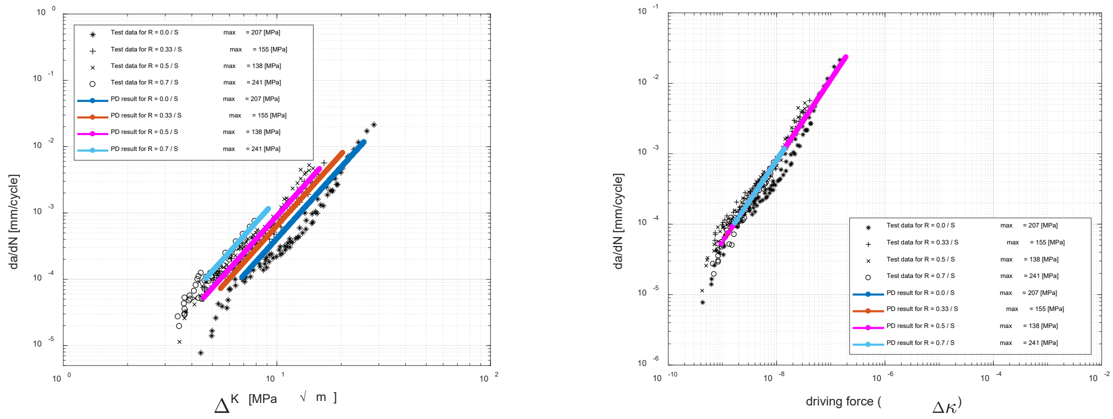
a) Crack length: 33 mm
Loading cycles: 3956

b) Crack length: 71 mm
Loading cycles: 5400

c) Crack length: 99 mm
Loading cycles: 6422

d) Crack length: 133 mm
Loading cycles: 7625

Fig. 1. Deformation results with a growing crack at R = 0.0/$S_{\max}$ = 207 MPa for 2024-T3 aluminum alloy; a) Crack length: 33 mm; b) Crack length: 71 mm; c) Crack length: 99 mm; d) Crack length: 133 mm; the displacement in the y direction (unit: mm) are exaggerated with a factor of 60.



a)

b)

Fig. 2. Crack growth prediction curves at different R-ratio loading conditions for 2024-T3 aluminum alloy as a function of a) stress intensity factor range; b) two-parameter based PD driving force.

## 3. Conclusions

A new two-parameter remaining-life equation in a PD fatigue model is developed based on two controlling parameters of cyclic bond strain and maximum cyclic strain. The proposed PD model on the basis of two-parameter remaining-life allows a unification of fatigue damage modeling to simulate material deformation and crack propagation for cyclic loadings at various R-ratios. The crack growth results predicted by the proposed model correlate well with experimental crack growth data.

## References

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