

# A Robot Application for Fatigue Tests to Estimate Life Time of Metal Parts

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**Abstract.** Propagation behaviour has a remarkable importance because the rate and the size of propagation may result in significant failures and thereby costs. It is a necessity that the determination of these insidiously proceeding cracks just in the right time and providing the sustainability of conformity to the specified quality standards in a safe way.

This study plans to integrate a thermographic camera on to Mobile Robot in order to make easier to scan all area hard to reach. By this way non-destructive tests for fatigue detection and accordingly quality control of metal worked on can be performed efficiently. Conventional fatigue tests are costly and impractical. Correspondingly, these negative conditions force firms to replace parts ahead of time or belatedly. These two cases are both undesirable and make difficult to establish maintenance policy.

## 1. Introduction

Fatigue failures occur when metal is subjected to a repetitive or fluctuating stress and will fail at a stress much lower than its tensile strength. Fatigue failures occur without any plastic deformation and don't reveal any warning [6].

Basic Factors causing a fatigue failure are; a maximum tensile stress of sufficiently high value, a large amount of variation or fluctuation in the applied stress, a sufficiently large number of cycles of the applied stress [6].

Stress concentration, corrosion, temperature, overload, metallurgical structure, residual stress and combined stress may be defined as additional failure factors.

Fatigue crack propagation is divided to 3 stages as: Non propagating fatigue crack, stable fatigue crack propagation and unstable fatigue crack propagation [6]

Conventional fatigue testing which requires a long period of time and a lot of costs cannot be a good solution to those concerns thermography could become used for the estimation of fatigue limits because the noise equivalent temperature difference of infrared cameras has been so dramatically enhanced as to develop non-contact and non-destructive inspection technologies for full-field stress analysis [7].

For the more precise estimation of the life of the metal, the more efficient measurement results are needed. This kind of convenience proposed in this study make possible to determine the optimal replacement period of crucial metal parts of the machines or vehicles.

## 2. MOBILE ROBOT

Review Stage A two wheeled mobile robot is a class of benchmark non holonomic system due to the its kinematic constraints [1,2]. Researchers have widely investigated wheeled mobile robot (WMR), because of its extensive application in many areas such as agriculture, service platforms, industry, assistive medical applications, national defense industry, etc. [3,4,5].



Agricultural Mobile Robot



Industrial Mobile Robot



Assistive Medical Mobile Robot

### 2.1. Mathematical Model

The model of a mobile robot in a 2-D Cartesian workspace adopted is shown in Fig. 1. For the purpose of analysis, two coordinate systems are defined. The global coordinate system  $\{X, O, Y\}$  is fixed to the Cartesian workspace and the local coordinate system  $\{U, C, V\}$  is attached to the mobile platform, where  $U$  is the driving direction (longitudinal direction),  $V$  is the lateral direction (latitudinal direction), and  $C$  is the robot center point. The configuration of the mobile robot can be defined as the following vectors:

$$\theta = [\theta_L \quad \theta_R]^T, \quad \omega = [\omega_L \quad \omega_R]^T, \quad P_c = [x_c \quad y_c \quad \varphi_c]^T \quad (1)$$

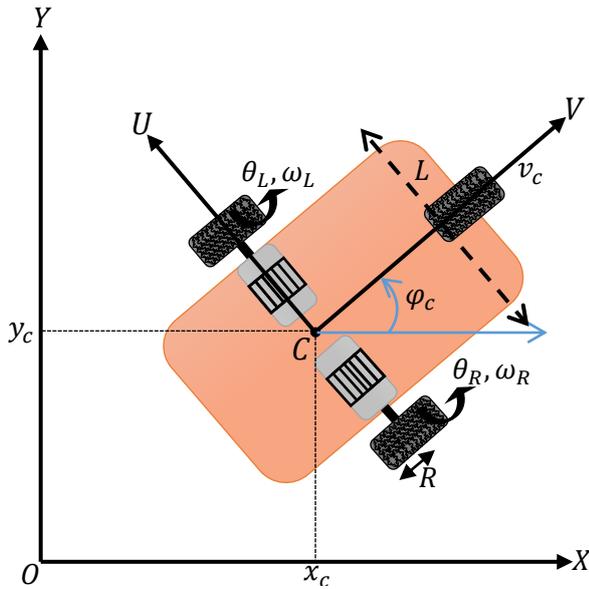
where

$\theta_L, \theta_R$ ; Rotational angles of the left and the right wheel

$\omega_L, \omega_R$ ; Angular velocity of the left and the right wheel

$x_c, y_c$ ; Spatial position of the mobile robot center  $C$

$\varphi_c$ ; Heading angle of the mobile robot with respect to point  $C$



**Fig.1** 2-D Model of mobile robot

On the conditions of nonslipping, we can write the following kinematic equations in velocity dimension;

$$v_R = R \cdot \omega_R \tag{2}$$

$$v_L = R \cdot \omega_L \tag{3}$$

$$v = \frac{v_R + v_L}{2} = \frac{R}{2} (\omega_R + \omega_L) \tag{4}$$

$$\begin{bmatrix} \dot{x}_c \\ \dot{y}_c \\ \dot{\varphi} \end{bmatrix} = \begin{bmatrix} \frac{R}{2} \cos(\varphi) & \frac{R}{2} \cos(\varphi) \\ \frac{R}{2} \sin(\varphi) & \frac{R}{2} \sin(\varphi) \\ \frac{R}{L} & -\frac{R}{L} \end{bmatrix} \begin{bmatrix} \omega_R \\ \omega_L \end{bmatrix} = J_{aco} \cdot \dot{\theta} \tag{5}$$

where  $L$  is tread between wheels and  $R$  is radius of driving wheels.  $v_R$  and  $v_L$  present the linear velocity of the right and left wheels,  $v$  is the vehicle linear velocity and  $J_{aco}$  is Jacobian matrix of the mobile robot.

## References

- [1] Robust tracking control for wheeled mobile robot based on extended state observer (Hongjiu Yang, Xiaozhao Fan, Yuanqing Xia & Changchun Hua)
- [2] Adaptive output feedback tracking control of a nonholonomic mobile robot (Jiangshuai Huang, Changyun Wena, Wei Wangb,1, Zhong-Ping Jiang)
- [3] Palacin J., Palleja T., Valganon I., Pernia R., Roca J., Measuring coverage performances of a floor cleaning mobile robot using a vision system, In: Proceedings of the IEEE International Conference on Robotics and Automation, 2005, pp.4236–4241.
- [4] Noonan T.H., Fisher J., Bryant B., Autonomous Lawn Mower, U.S. Patent 5,204,814, 1993.
- [5] Evans J.M., Help Mate: an autonomous mobile robot courier for hospital, in: Proceedings of IROS'98, 1998, pp. 1695–1700.

- [6] Udomphol Tapany, *Fatigue of Metals Lecture Notes*, Suranaree University of Technology, May-August 2007.
- [7] Kim W-T, Choi M-Y, Huh Y-H, Eom S-J, *Measurement of Thermal Stress and Prediction of Fatigue for STS Using Lock-In Thermography*, 12th A-PCNDT 2006 – Asia-Pacific Conference on NDT, 5th – 10th Nov 2006, Auckland, New Zealand.
- [8] Campbell, F.C., 2012. *Fatigue and Fracture: Understanding the Basics*. ASM International.
- [9] B. Yeter, Y. Garbatov, C. Guedes Soares' *Evaluation of fatigue damage model predictions for fixed offshore wind turbine support structures*; *International Journal of Fatigue* Volume 87, June 2016, Pages 71–80.
- [10] Pokorny P., Hutar P., Nádler L. *Residual fatigue lifetime estimation of railway axles for various loading Spectra*, *Theoretical and Applied Fracture Mechanics* 82 (2016) 25-32.