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A service reliability assessment method for the rigidity-flexibility coupling open arc welding robot

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Abstract. The open arc welding robots have been used widely nowadays; however, the elastic deformations of every inner link inevitably affect the welding quality. In this paper, it proposes an effective method of service reliability assessment for the rigidity-flexibility coupling open arc welding robot. Firstly, a parametric virtual model of the robot is built in 'ADAMS/View-AutoFlex' module. Secondly, the stochastic errors generated in the working process are simulated by a program created from pseudo-random numbers which have been written by multiplicative congruence method. Lastly, Monte Carlo sampling calculation is implemented for the virtual model, and large sample data of the dynamic characteristics in welding process are obtained and used to calculate the service reliability of the welding robot. This method includes simplicity (no need to solve complex mathematic model) and high accuracy which make it highly promising for application in mechanism design.

Introduction

Traditional engineering analysis always overlooked the system inner variability, and used mean parameters in place of the actual structures. If the system variations are obvious or the variations are not homogeneous, the analysis will deviate from the real value. Generally, the randomness of the engineering structures may be material randomness, dimension randomness, boundary condition randomness, and physical property randomness. Meanwhile, the dynamic response of a certain system varies with the place, environment, and time of use even if the system itself does not change.

An open arc welding robot is composed of pinion-and-rack gear, screw-driven, guide rail sliding. Motion accuracy of the welding gun head is a main factor affecting the welding quality. Therefore, how to evaluate the effects of its elastic deformations on the system motion accuracy is very important in improving the system design quality. Otherwise, there inevitably exist minor flexible deformations in each inner link, once we take them into account, the results will be more accurate.

Assessment method for the service reliability of the rigidity-flexibility coupling open arc welding robot

Using this method, stochastic errors generated in the process of machining and installation must to be statistic by way of using VC++ software; meanwhile, Monte Carlo method is used in obtaining the dynamic large sample data in the robot working process, and these are crucial for the service reliability assessment. Fig.1 shows the analysis process.

Simulation of the rigidity-flexibility coupling open-arc welding robot

Modeling of the virtual robot The open-arc welding robot, as shown in Fig.2. According to the dimensions marked in detail drawings, a virtual model of the welder is built, as shown in Fig.3, and five kinematic pairs are applied on the model: fixed, rotating, sliding, screw pairs, and gears.

A rigidity-flexibility coupling model will be built when the elastic deformation of each liner are not ignored, especially in swing cross beam. The steps to create flexible bodies are:

1. Add ‘ADAMS\AutoFlex’.

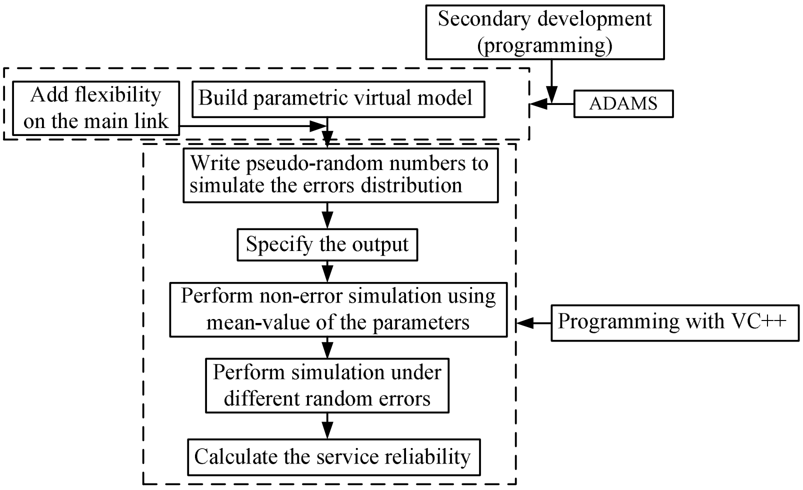


Fig.1 Service reliability analysis flow of the open arc welding robot

Fig.2 Arc welding robot in working

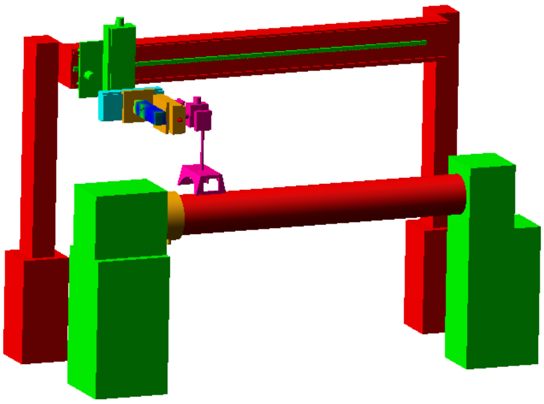


Fig.3 Virtual model of the welder

2. Generate a ‘.mnf’ file, chose the flexible element and its attribute, and click ‘Attachment’ to chose the surface that connects the flexible bodies and rigid bodies.

3. Connect the rigid bodies with fixed pairs and constraints, and these constrains are applied between the flexible bodies and the dummy element (the mass and inertia are zero).

Finally we can build a finite element model of the flexible body, such as the swing cross beam (Fig.4).Driving forces are to be loaded on the rigidity-flexibility coupling model; the driving functions are listed in Tab.1. Where, MOTION_1 is loaded on the screw mechanism to let the welder to move down from 0 to 5s; MOTION_2 is loaded on the swing mechanism to let the welder to swing from 6s; MOTION_3 is loaded on the gears to let the gun head to walking step by step at the 26s, the 46s, the 66s, and the 88s at 30mm per time.

Simulation of the rigidity-flexibility coupling model Define simulation time=90s, and simulation steps= 60, thus we can obtain the motion curves (Fig.5).

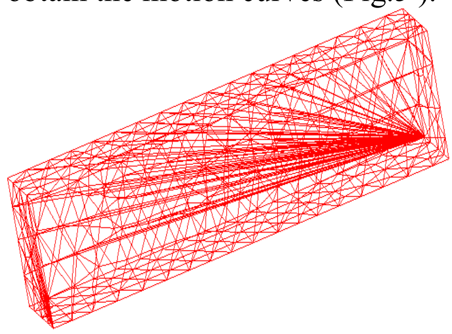
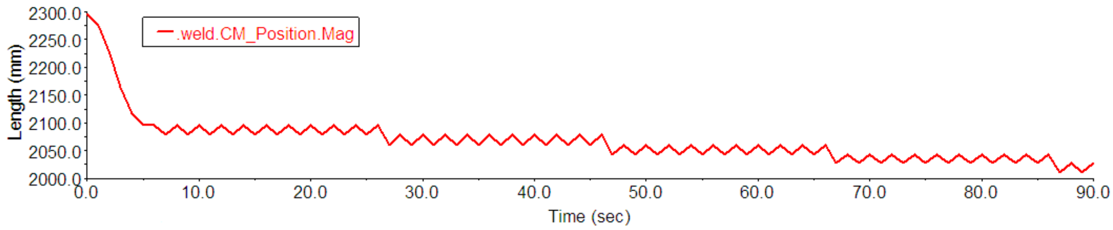


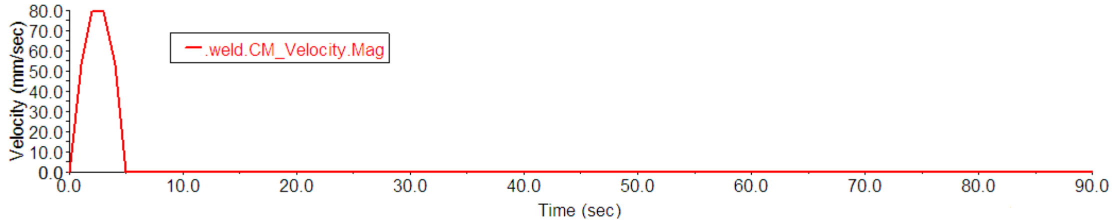
Fig.4 Cross beam's flexible model

Tab.1 PUMA560 robot driving functions

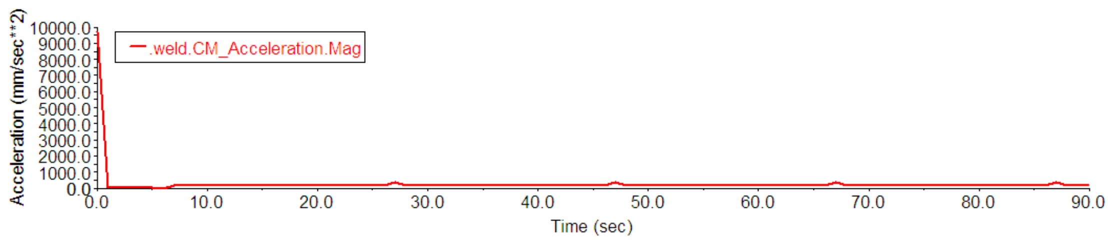
name	Joint	type	function
MOTION_1	Joint_7	Revolute	STEP(time , 0 , 0d , 5 , 1800d)
MOTION_2	Joint_8	Revolute	STEP(time , 6 , 0d , 7 , 360d)+STEP(time , 7 , 0d , 8 , -360d)+….+STEP(time , 88, 0d , 89,360d)+STEP(time , 89, 0d , 90,-360d)
MOTION_3	Joint_6	Revolute	STEP(time,26,0d,27,62.5d)+STEP(time,46,0d,47,62.5d) +STEP(time,66,0d,67,62.5d)+STEP(time,86,0d,87,62.5d)



(a) Displacement curve of the gun head



(b)Speed curve of the gun head



(c) Acceleration speed curve of the gun head

Fig.5 (a～c) Motion curves of the welding robot

From the calculation, we can learn that the gun head speed changes homogeneously, but when it moves approach to the work piece, the accelerate speed reduces sharply. It means that the flexible model's deformation varies in a wide range, and shows high non-liner..

Service reliability assessment of the welder A common analysis system of the service reliability of the welder is created using VC++ software and ADAMS-APDL. It contains three key modules, pre-processing, service reliability analysis, and post-processing. Pre-processing module is used to create parametric virtual model and apply constraints and loads. Service reliability analysis module is the main block to program a user-defined function of pseudo random numbers conforming to

Gaussian distribution, and modifies the design variables to realize Monte Carlo parameterization. Post-processing module is used to define error allowable boundary conditions and evaluate mechanism service reliability at any time.

With this service reliability analysis system, we can perform 20, 100, and 500 times simulations on the mechanism to calculate the Eigen-values for displacement limit error (μ_0,σ_0)=(0.15,0.05), allowable speed limit error (μ_{v0},σ_{v0})=(0.45,0.05), and allowable acceleration speed limit error (μ_{a0},σ_{a0}) =(2,0.05).Lastly, the motion reliabilities of the mechanism end actuator can be calculated (Tab.2).

Tab.2 Service reliability of the welding robot

Times \ Time		4s	20s	47s
20	displacement	0.963646	0.963811	0.961513
	speed	0.971454	0.971112	0.971276
	acceleration speed	0.994213	0.997449	0.997450
100	displacement	0.971854	0.973155	0.969978
	speed	0.970476	0.971283	0.971123
	acceleration speed	0.998077	0.998243	0.997442
500	displacement	0.973161	0.973051	0.971276
	speed	0.969744	0.971246	0.971265
	acceleration speed	0.998027	0.998622	0.998622

Conclusions

It proposes an effective method for the service reliability assessment for the welding robot when considering the affect of the main part's elastic deformation, and functions as an analysis bases for the dynamic optimum design and reliability sensitively analysis.

It composes the advantages of the ADAMS and VC++ software to consider the dependence between random errors, which can improve the accuracy and efficiency of the mechanism design.

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References

[1] Shanzeng Liu, Zhencai Zhu. Frequency Analysis of a Spatial Rigid-flexible Coupling Parallel Manipulator. Chinese Journal of Mechanical Engineering,2011,Vol.47,No.23,pp 39-41

[2] Chang Li, Xing Han. Reliability virtual test of mechanism motion accuracy[J]. Journal of machine design, 2007,24(11):17-20.

[3] Weiguang An, Yinlin Cai. Reliability analysis and optimistic design of the random mechanism system[M], Harbin: Publication of Harbin engineering university, 2005,26(10):1175-1182.

[4] Tiejun Wang: Motion Reliability Simulation Based on ADAMS of A Serial-link Robot[D],Shenyang: Northeastern University, 2006. In Chinese.

[5] Tao Yu, Tingting Li. Dynamic Simulation for Rigid-flexible Coupling Model of Slider-crank Press based on ADAMS. Journal of Mechanical Transmission. 2012(3), 64-66

[6] Yi Wang, Liyan Wu, Liu Geng. Research of Modeling Flexible-rigid System Based on Mechanism. Journal of System Simulation, Vol.19 No.20, Oct.,2007,pp4708-4710

[7] Xing Han, Chang Li. A Study on the 6-6 Stewart Parallel Mechanism Dynamics in ADAMS. The 2012 3rd International Conference on Advances in Product Development and Reliability (PDR2012).Vol.544(2012),pp67-71