RESEARCH OF FRACTURE MECHANICS PROPERTIES OF $ZG0Cr_{13}Ni_4Mo$

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INTRODUCTION

Up till now, the main parameter, which was considered in the design of hydro-power runner, is the static strength. It was shown by practical investigation that under the action from both centrifugal force and hydrodynamic force, appearance of cracks in the blades of hydropower turbine has become unavoidable, furthermore, there has even occured the events of dropping partJ off the blades caused by the propagation of cracks.

It was not enough that to verify the blades design with static strength theory only, and to concentrate alone on the values of usual property, such as strength and plasticity. Especially, it seems unavoidable that the various technological defects should present in the component. They may play the role as a crack source under certain condition. So it is necessity using the concept of fracture mechanics to study the service ability of blades under working condition. In this paper we measured and studied the main fracture mechanics properties of $ZG0Cr_{13}Ni_4Mo$ with low carbon lath martensite matrix containning various content of reverse austenite.

MEASURED RESULTS OF MAIN FRACTURE MECHANICS PARAMETERS

1, Measurement of J_R and K_{J_R}

Based on the suitable ratio of a/w, five heat treatment technologies have been designed. The mechanical properties are given in Table 1. The specimens were taken from Y-type testblock, the measured particular values of J_R are given in Table2.

2. Determination of ΔK_{th}, $[\Delta K_{th}]_{cF}$, da/dN, $[da/dN]_{cF}$ And N

In oreder to determine the values of ΔK_{th}, $[\Delta K_{th}]_{cF}$, da/dN, $[da/dN]_{cF}$ and N, the number of stress cycle related the stage of the crack initiation of the material of blades, three heat treatment technologies, No.1, No.2 and No.5 are chosen from Table 1. The tests were performed under air and water medium respectively, loading frequency was either f_H=125-150 Hz or 20 Hz, load ratio was R=0.5. The results were given in Table 3 and Fig. 1 respectively.

It must be noted that in order to investigate the influence of practical defects, some specimens containning the porosity-typed defects or inclusion-typed defects have been tested to determine the values of the crack propagation rate of material under the previous condition, however, the loading frequency was f_H=125-150 Hz only. The results are shown in Fig. 2.

DISCUSSION

1. Ductile Fracture Toughness

As shown in Table 2, all of the values measured of J_i obtained from five heat treatment technologies were higher than 9 kgf/mm. However, for No.4 and No.5, which give higher strength values, their particular values of J_R are obviously lower than that of No.1 and No.2, which give the lower strength values.

2. ΔK_{th}, $[\Delta K_{th}]_{cF}$, da/dN, $[da/dN]_{cF}$ and N, the Number of Stress Cycle Related to the Stage of Crack Initiation

From Table 3, all of the values of ΔK_{th} and $[\Delta K_{th}]_{cF}$ of No.5 are lower than that of No.1 and No.2, although the strength values of No.5 are higher than that of No.1 and No.2. Under water medium, either of the loadings with higher or lower frequency condition, all of the values of

$[da/dN]_{cF}$ of No.5 over the range of lower value of ΔK are lower than that of No.1 and No.2, apart from the loading with higher frequency, air condition, where appears no obvious distinction among them. Furthermore, the extension of the area of ΔK tends to pass from the lower end to the higher one, as the loading frequency tends to the lower grade. From Table 3, under loading with lower frequency, water medium, N, the number of stress cycle related to the stage of crack initiation was lower than that of No.1 and No.2, even is approximately two-thirds of that of No.1.

PRELIMINARY CONCLUSIONS

(1) The structure of $ZGOCr_{13}Ni_4Mo$ consists of low carbon lath martensite matrix with higher density of dislocation and suitable content of reverse austenite with dispersive scattered speciality. Due to these two factors, the energy was absorbed by the matrix in the process of plastic strain and strengthenning caused by the phase transition from γ-M appeared in the strain area, then the material cauld be given higher values of fracture mechanics parameters, under certain condition.

(2) The low carbon lath martensite matrix, Cr_{13}-Ni_4 series steel, it seems unfavorable that to concentrate on tensile and yield strength value of material alone. The suitable heat treatment technology may be chosen based on the principal fracture mechanics parameters of $ZGOCr_{13}Ni_4Mo$. Particularly, on those obtained under working conditions of the blades.

(3) For increasing the service ability of $ZGOCr_{13}Ni_4Mo$, it also seems unfavorable from view-point of design, to concentrate on tensile and yield strength values alone, and it is not perfect to verify the design ability of blade by static strength theory only.

(4) From the properties of de/dN and $[da/dN]_{cF}$ obtained from the specimens containning the practical defects, it is necessary to study deeply in both theory and practice. It will provide the valuable information for evaluating the material of blades, which contain the practical defects.

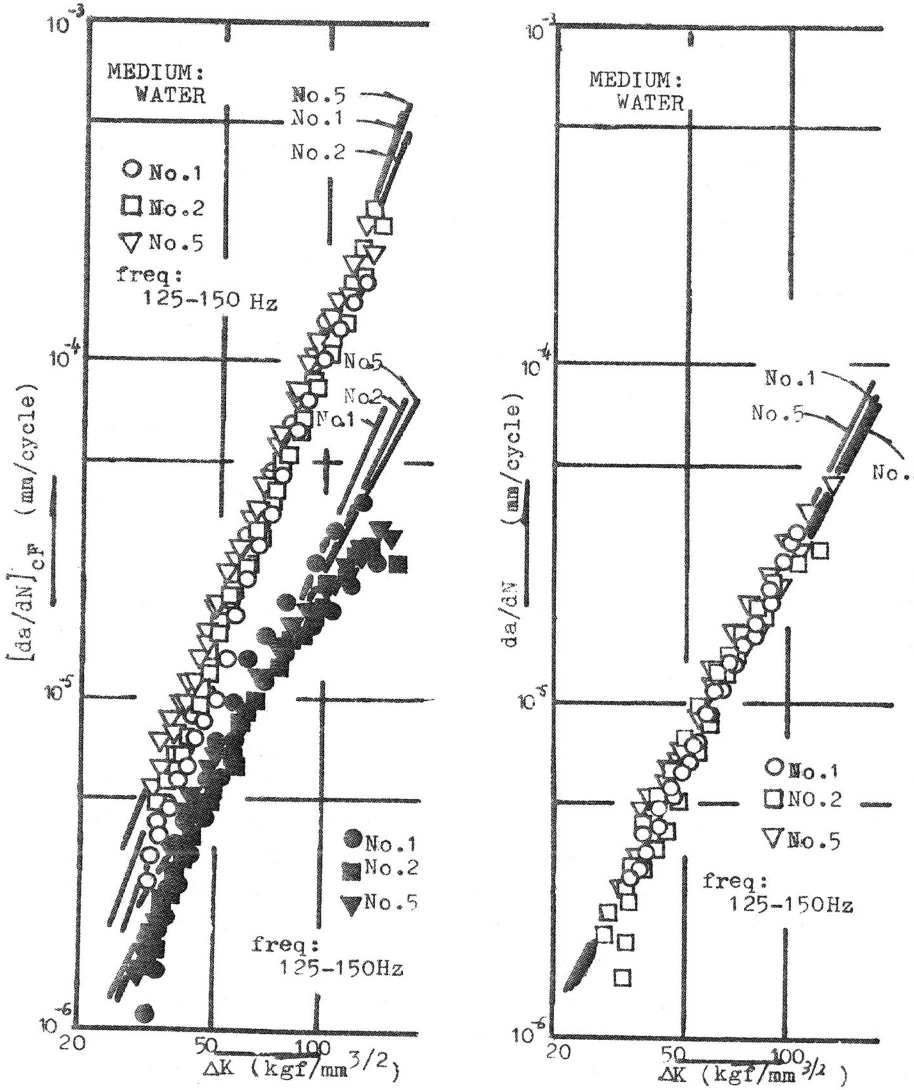

Fig.1 Diagram showing relationship between log(da/dN), log$[da/dN]_{cF}$ & log(ΔK)

Table 1 Mechanical Properties

Tech. number	σ_b ($\frac{kgf}{mm^2}$)	σ_s ($\frac{kgf}{mm^2}$)	δ (%)	ψ (%)	α_K $\frac{kgf\text{-}m}{cm^2}$
1	84.2	57.0	19.9	58.6	14.5
2	82.7	64.3	20.3	56.3	14.5
3	83.5	63.5	19.3	57.3	15.3
4	86.5	75.5	16.8	48.3	14.1
5	105.1	99.1	12.0	50.4	11.1

Table 2 Schedule of Regression Results

Tech. number	Regression equation	J (kgf/mm)			K_{JR} (kgf/mm$^{3/2}$)		
		J_i^*	$J_{0.05}^*$	$J_{0.2}^*$	K_{Ji}	$K_{J.05}$	$K_{J.2}$
1	$J_R = \frac{1}{.01396+\frac{0.01171}{\Delta a+.009}} \pm .76$	10.45	13.95	20.90	491.07	567.38	694.48
2	$J_R=9.45+45.95\Delta a \pm 1.57$	11.70	14.05	20.90	519.62	569.41	694.48
3	$J_R=\frac{1}{.02206+\frac{.009165}{\Delta a+.094}} \pm 1.83$	11.00	14.55	20.10	503.83	579.46	681.06
4	$J_R=\frac{1}{.01993+\frac{.01219}{\Delta a+.098}} \pm .74$	9.30	12.05	18.15	463.27	517.33	647.18
5	$J_R=8.74+37.90\Delta a \pm 1.85$	10.32	12.00	17.95	488.01	526.23	643.61

* J_i, $J_{0.05}$ & $J_{0.2}$: The particular value of J_R corresponding to the crack initiating point, the point at which the crack length has grown up to 0.05 mm & 0.2 mm respectively.

Table 3 Measured and calculated results

Tech. No.	Freq. (Hz)	Medium	C (mm/cycle) C_u	C_L	n	ΔK_{th} or $(\Delta K_{th})_{cF}$ ($kgf/mm^{3/2}$)	N (cycle)
	125-150	air	3.26×10^{-9}	2.38×10^{-9}	1.97	19.27	
1	125-150	water	7.69×10^{-9}	2.34×10^{-10}	2.41	15.79	
	20	water	6.25×10^{-11}	3.96×10^{-11}	3.18		31905
	125-150	air	4.68×10^{-9}	1.44×10^{-9}	1.97	18.46	
2	125-150	water	1.18×10^{-9}	8.79×10^{-10}	2.18	13.55	
	20	water	2.13×10^{-10}	1.62×10^{-10}	2.87		27407
	125-150	air	2.72×10^{-9}	1.83×10^{-9}	2.04	14.30	
5	125-150	water	3.63×10^{-9}	1.74×10^{-9}	1.99	12.70	
	20	water	4.74×10^{-10}	3.33×10^{-10}	2.74		20151

Note: C and n are the cofficient and exponent in regression equ. (which has the form of $da/dN=c(\Delta K)^n$) respectively.

C_u and C_L are the upper and lower limit of scatter blet respectively.

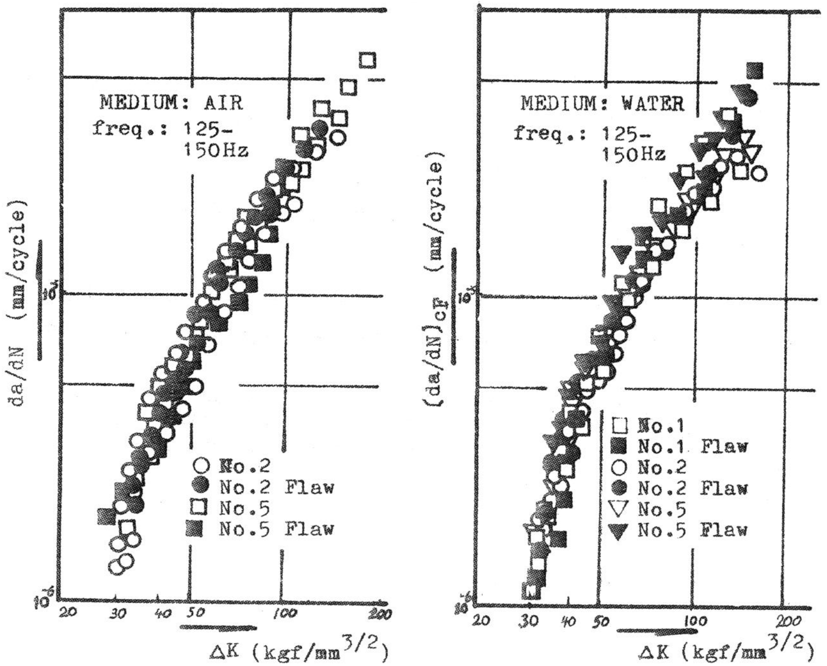

Fig.2 Diagram showing the influence of practical defects on the rate of crack propagation