Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 37 (1982)

Artikel: Fatigue research on welded crane runway girders
Autor: Umino, S. / Mimura, H.
DOI: https://doi.org/10.5169/seals-28957

Fatigue Research on Welded Crane Runway Girders

Recherches de fatigue sur les poutres-supports soudées des ponts roulants

Ermüdungsversuche an geschweissten Kranbahnträgern

S. UMINO
Prof.
Tokyo Denki University
Tokyo and Saitama, Japan

H. MIMURA
Associate Prof.
Tokyo Denki University
Tokyo and Saitama, Japan

SUMMARY
This report presents the results of fatigue tests on welded crane runway girders. They indicate that weld cracks in the vicinity of the upper flange are affected by the local stresses caused by the eccentricity of the crane rail from the centre line of the girder.

RESUME
Cet exposé présente les résultats d'essais de fatigue sur des poutres-supports soudées de ponts roulants. Ils indiquent que les fissures dans les soudures des ailes supérieures des poutres sont affectées par les contraintes locales dues à l'excentricité du rail du pont par rapport au centre de la poutre.

ZUSAMMENFASSUNG
Der Artikel beschreibt die Resultate von Ermüdungsversuchen an geschweissten Kranbahnträgern. Es zeigte sich, dass die Risse in der Nähe des oberen Flansches von den örtlichen Spannungen beeinflusst werden, welche infolge der Exzentrizität der Kranschiene bezüglich der Mittellinie des Trägers auftreten.

1. INTRODUCTION

A welded craneway girder under high wheel loads and high loading cycles usually develops cracks in these places;(1)the fillet welds between the web plate and upper flange;(2)the fillet welds between the rib plate and horizontal stiffener ;(3)the fillet welds between the web plate and rib plate, or the fillet welds between the upper flange and vertical stiffener. These weld fractures occur only in the vicinity of the upper flange of welded craneway girder. One of the possible reasons for these weld fructure is the effect of the local stresses caused by the eccentricity of the crane rail from the center line of girder.

A craneway girder is designed in accordance with the generally accepted procedure, based on static loads and in accordance with the Japanese Standard-Specification for the Design of Steel Structures.

Impact factors are usually introduced in this procedure to represent the effect of dynamic loadings, while the horizontal force acting in the transverse direction is defined as 10% of the wheel load. However, the local stresses caused by the eccentricity of the crane rail are not taken into consideration yet.

The present study is intended to discuss the weld fractures in the vicinity of the upper flange of the craneway girder, based on the fatigue test results carried out at Tokyo Denki University.

2. TYPES OF FATIGUE CRACK IN THE WELDED CRANEWAY GIRDER

An example of the relation between the location of the fatigue crack initiated and the eccentricity of crane rail is shown in Fig.1 of craneway girders in a mill building. These craneway girders are simply supported beams of 12M span supporting 2 cranes of 39M span. The cross section of these girders is built-up

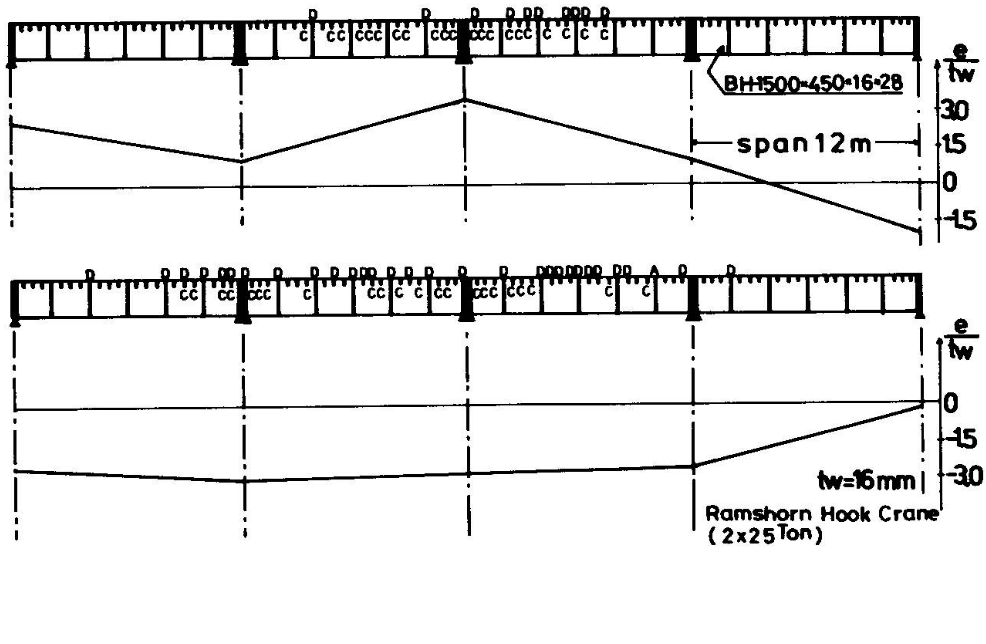

Fig.1 An example of the relation between the location of fatigue crack initiated and the eccentricity of crane rail

H shape of 1500mm depth, 450mm width of flange, 16mm thickness of web and 28mm thickness of flange, and vertical ribs are attached at the web plate beneath the upper flange. The crane rail, with a thick resilient pad laid under it, is a 74 Kgf/M(JIS E 1103) laid on the craneway girder. The serviced cranes are two overhead travelling cranes with 4 wheels per rail respectively. The rated loads of the cranes are 25Tonf. Maximum wheel loads of the cranes are 35Tonf respectively.

The fatigue cracks which were initiated in these girders were observed after a service period of only 7 years. The estimated number of the cycles of loading is about $5x10^5$.

The cracks which will occur in the vicinity of the upper flange where e/tw are more then about 3 are shown in Fig.1. (e: eccentricity of crane rail from the center line of girder, tw: thickness of web plate)

Fig.2 shows typical patterns of fatigue crack initiated in a welded craneway girder. For the sake of convenience in this report, the types of cracks which will be dealt with are identified as follows.

Type A crack; crack in the fillet welds between the web and the upper flange

Type B crack; crack in the fillet welds between the rib and the horizontal stiffener

Type C crack; crack in the welds between the rib and the web plate

Type D crack; crack in the welds between the upper flange and the vertical stiffener

Type E crack; crack in the lower flange

(the Type E crack is not dealt with in this report.)

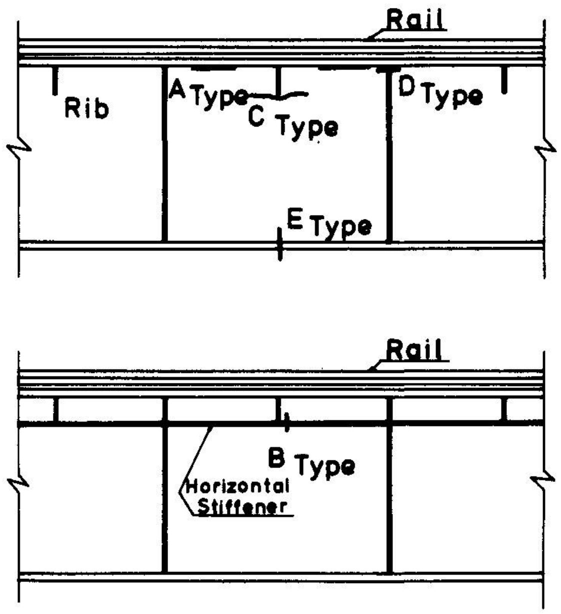

Fig.2 Types of fatigue cracks

3. TEST SPECIMENS AND EXPERIMENTAL METHOD

The details of the tested specimens are shown in Fig.3, and the dimensions of the specimens are shown in Table 1. The kind of steel used in these specimens is JIS-SS41 (structural cabon steel with minimum specified tensile strength of 41 Kgf/mm^2).

These specimens were fabricated by a submerged-arc weld at the fillet weld connection of flange to web, and by a manual weld at the fillet weld connection of the rib to the web and the stiffener to the web. All of these specimens were tested under as welded condition.

The mechanical properties and chemical compositions of the steel used are summarized in Table 2.

The tested girder was simply supported and concentrated load was applied midspan of it though the crane rail (37 Kgf/M) as shown in Fig.4.
A repeated load was applied with 1∿3 Hz in one direction by 50Tonf electro-hydraulic fatigue testing machine.

The initiation and propagation of fatigue cracks were observed using a dye penetrant inspection.

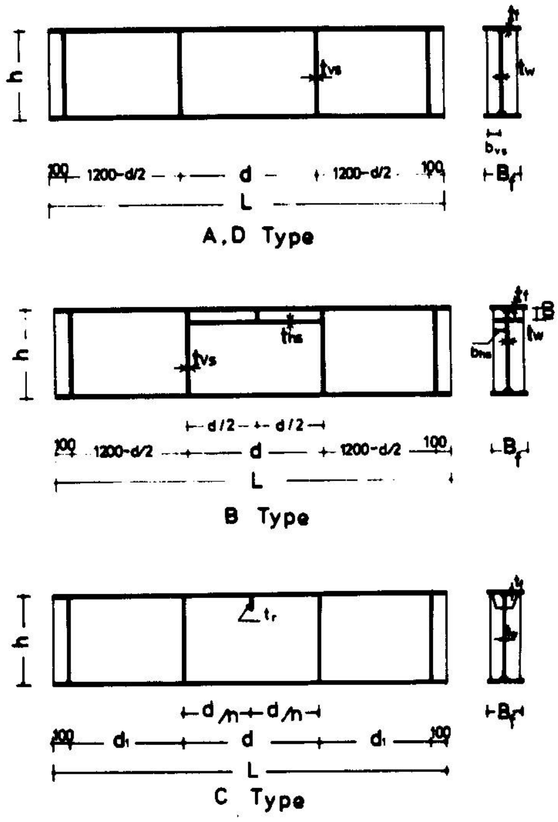

Fig.3 Tested specimens

Table 1 Dimensions of specimens

specimens	Lcm	hcm	dcm	Bfcm	tfmm	twmm	bvscm	tvsmm	bhscm	thsmm	brcm	trmm
BG16- 9- 900/2(9)	240	59.8	90.0	24.1	15.61	8.88	9.1	8.79	10.2	8.69	10.0	8.76
BG16- 9- 900/2(9)	240	59.6	90.0	24.1	15.96	8.87	9.1	8.79	10.0	8.73	10.0	8.76
BG19- 9- 900/2(12)	240	58.0	90.0	24.0	18.99	8.80	10.0	8.80	10.0	11.78	10.0	8.80
BG16- 9- 900/2(9)	240	59.7	90.0	24.1	15.99	8.96	9.1	8.79	10.2	8.74	10.0	8.76
BG16- 6- 600/2(6)	239	57.8	59.8	24.0	15.74	5.80	10.0	5.81	10.0	5.81	10.0	5.82
CG16- 9- 900/2(9)	240	60.0	90.0	24.0	15.66	8.66	9.0	8.85			9.0	8.85
CG16- 9- 900/2(9)	240	59.7	90.2	24.1	15.65	8.85	9.0	8.85			9.0	8.86
CG16- 9- 900/2(9)	240	59.7	90.1	24.1	15.67	8.85	9.0	8.85			9.0	8.85
CG16- 9- 900/2(9)	240	59.8	89.8	24.0	15.62	8.86	9.0	8.86			9.0	8.86
CG16- 9- 900/2(9)	240	60.0	89.9	24.0	16.64	8.84	9.0	8.85			9.0	8.84
CG16- 9- 900/2(9)	240	59.9	90.1	24.1	15.66	8.86	9.0	8.86			9.0	8.86
DG16- 6- 600(6)	239	57.8	59.8	24.0	15.74	5.80	10.0	5.81				
DG22-12- 800(9)	240	57.8	80.0	24.1	21.77	11.79	9.1	9.02				
DG19- 6- 600(6)	240	57.9	90.0	24.0	18.92	5.66	10.1	5.73				
DG16- 9- 900(9)	240	59.8	90.1	24.1	15.64	8.86	9.0	8.80				
DGH19-9- 800(12)	240	40.0	79.8	23.9	18.73	8.76	10.5	11.65				

Table 2 Mechanical properties and chemical composition

specimens	plate(mm)	$\sigma_y (t/cm^2)$	$\sigma_B (t/cm^2)$	Elon.(%)	Cx100	Six100	Mnx100	Px1000	Sx1000	
B-Type	6	3.34	4.64	25.64	12	25	77	22	7	SH
	9	3.10	4.29	29.03	12	19	77	21	14	
	12	2.91	4.26	29.61	10	20	67	20	12	
C-Type	9	2.40	4.04	32.65	12	19	77	21	14	W
A/D-Type	6	3.34	4.64	25.64	12	25	77	22	7	Sv
	9	3.10	4.29	29.03	12	19	77	21	14	
	12	2.80	4.28	30.33	10	30	67	20	12	

SH; Horizontal Stiffener, W; Web, Sv; Vertical Stiffener,

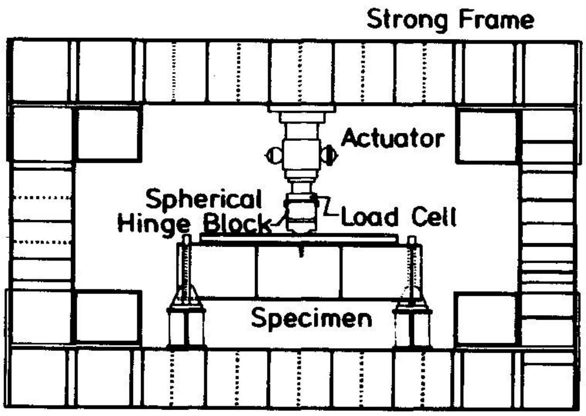

Fig.4 Test set-up

4 TEST RESULTS AND DISCUSSIONS

The fatigue test results are summarized in Table 3 and are illustrated in Fig.5 to Fig.8. In Table 3, ε_1 and ε_2 are the measured strains at the maximum load in the vicinity of the crack initiated on the eccentric side of rail and the opposite side respectively.

Nc represents the number of cycles up to cracks initiated and Nf represents the number of failures.

Nf of these specimens were defined at the number of cycles when the crack developped across the width of stiffener of the Type B and Type D specimens and when the crack in the web plate developped about 80mm in length of the Type C specimens. No Type A crack was observed in these tests.

The fatigue test results for the Type B crack are shown in Fig.5. In this figure, hollow circles represent Nc while solid circles represent Nf.

All of the Type B cracks initiated at the toe of the fillet welds between the rib and the horizontal stiffener. The fatigue crack-growth rate of Type B is about 0.9mm/10^4 cycles until the crack runs though the thickness of horizontal stiffener plate. After that, the crack-growth rate increases to 6mm/10^4 cycles. The crack-growth stopped when it reached the web plate.

Table 3 Results of test

specimens	$\varepsilon_1(\varepsilon_2)\times10^{-6}$	$Nc\times10^4$	$Nf\times10^4$	$P_{max}-P_{min}$(t)	Remarks
BG16- 9- 900/2(9)	1560(440)	14.5	42	20-2	
BG16- 9- 900/2(9)	960(270)	48	82	30-2	
BG19- 9- 900/2(12)	800(260)	52	120	30-2	
BG16- 9- 900/2(9)	580(160)	100	170	25-2	
BG16- 6- 600/2(6)	420(150)	—	240	25-2	
CG16- 9- 900/2(9)	2550(-2830)	(3)	6.8	25-2	
	2130(-2160)	4	10.5		
	1450(-2040)	10.6	26.5		
	1000(-1300)	46	64.5		
	450(-1000)	42	75		
	160(- 840)	75	200→		εt (εc)
DG16- 6- 600(6)	1300(- 645)	52	82	25-2	—
DG22-12- 800(9)	1050(- 80)	83	94	30-2	945(-1620)
DG19- 6- 600(6)	820(60)	115	135	30-2	665(- 870)
DG16- 9- 900(9)	600(- 145)	110	128	30-2	580(- 630)
DG22-12- 800(9)	450(- 40)	—	230→	25-2	400(-1250)
DGH19-9- 800(9)	350(- 135)	—	270→	20-2	450(-1235)

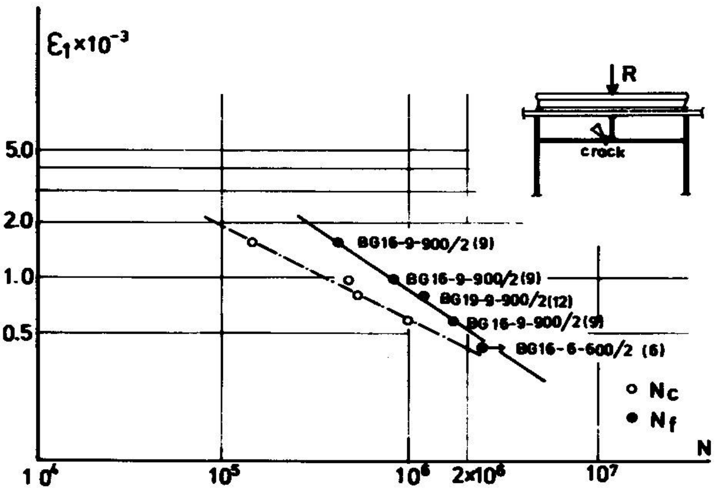

Fig.5 Fatigue test results of the Type B crack

The test results for the Type C crack are shown in Fig.6. All of the Type C cracks initiated at the toe of fillet welds between the rib and web plate at the end of rib. These tests show that the Type C crack appears at a very early loading cycle, even when the eccentricity of crane rail is not so great (e=0.5 tw). In this case, the value of normal stress of the flange is $0.56t/cm^2$, and the value of mean shearing stress of the web is $0.24t/cm^2$ at the maximum load (25Tonf).

The test results for the Type D crack are shown in Fig.7. In these tests, Type A and/or Type D cracks were expected to occur, however, the tests results showed the initiation of no Type A cracks. εc and εt, shown in remarks of Table 3, are the measured strains of the web beneath upper flange at the loading point on the eccentric side of rail and the opposite side respectively at the maximum load. All of the Type D cracks initiated at the toe of fillet welds between upper flange and vertical stiffener. The cracks developped along the toe of fillet weld. The crack-growth stopped when it reached the web plate.

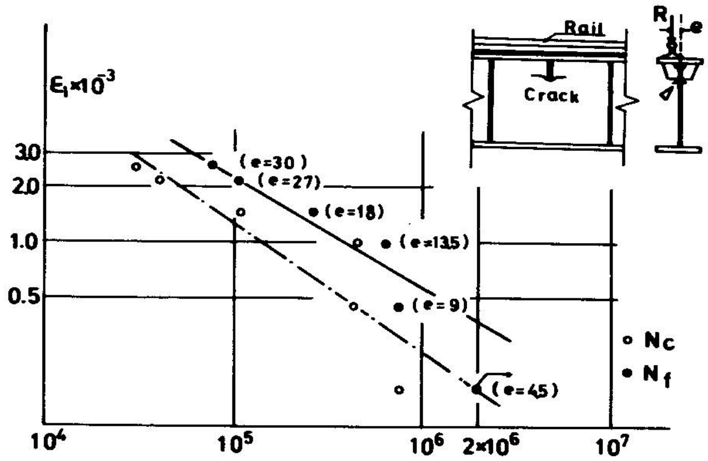

Fig.6 Fatigue test results of the Type C crack

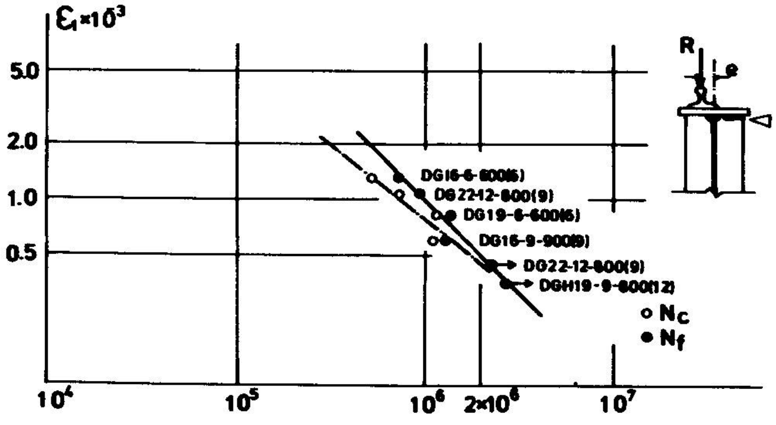

Fig.7 Fatigue test results of the Type D crack

Fig.8 shows the relation among magnitude of eccentricity of the crane rail from the center line of girder, e web plate thickness, tw wheel load, R girder depth, h distance between vertical stiffeners, d torsional rigidity of upper flange and crane rail, JG and fatigue life N obtained from test results. This figure shows that the fatigue lives of the Type B and Type D cracks are nearly equal for the magnitude of eccentricity of the crane rail while the effect of the eccentricity of crane rail is larger for Type C crack then for the Type B and Type D cracks.

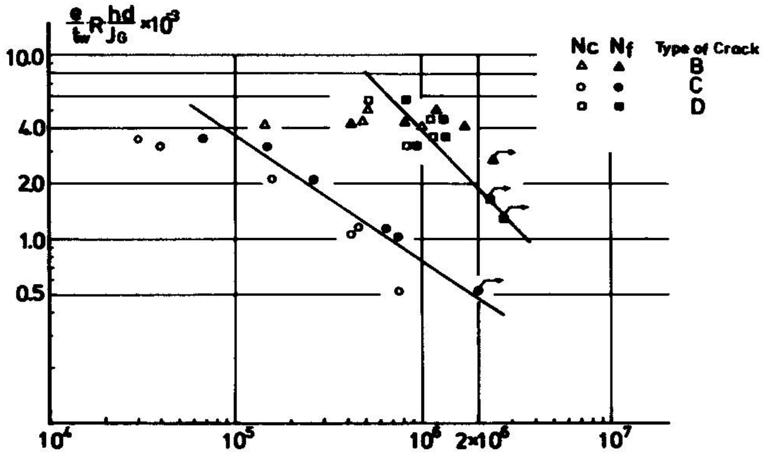

Fig.8 Relation between magnitude of eccentricity of crane rail from center line of girder and fatigue lives

5. CONCLUSION

It is concluded that the fractures in the vicinity of the upper flange of the welded craneway girder are caused by the eccentricity of the crane rail from the center line of craneway girder. Especially, Type C fatigue crack is more affected by the eccentricity of the crane rail. The fatigue lives of the Type B and Type D crack are nearly equal for the magnitude of eccentricity of the crane rail.

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