STRESS ANALYSIS OF HIGH SPEED FOUR BAR MECHANISM

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ABSTRACT

The multi-body four bar mechanical system is an rigid links assemblage of assumed revolute joints and crank rotating motion for complete cycle, the links which produce relative motion. In higher speed mechanisms the assumption of rigid body links will not be valid, as the links are subjected to greater deformations. The high-speed activation of four bar mechanism demands that the members of the operating mechanism be tough, durable, flexible and safe to withstand axial stresses and undue vibrations. The analysis of the four bar mechanism can be performed by using kinematic coefficients method and theoretical vector loop, multi body dynamic analysis soft wares and by using Video graphic analysis etc,. Commonly such mechanisms are analyzed using CAD packages, e.g. ANSYS, ADAM etc. The stress analysis of a four bar mechanism (at higher operating speeds) is analyzed to find the limiting high speed of the four bar mechanism and the results are presented.

KEYWORDS: ADAMS Software, Four Bar Mechanism & Multi Body Links Dynamics

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INTRODUCTION

The four bar is most simplest often times the most useful mechanism elements of the mechanisms which run at high speeds should be considered as flexible to maintain accuracy, to operate in its speed regime and prevent the failure arising out of stresses due to dynamic forces involved. The speed of the mechanism at which the inertia forces arises cannot be neglected and therefore have to be considered.

A planar four bar linkage can be used for many mechanical machinery is numerous, including to convert rotational motion to reciprocating motion or reverse, for some typical applications will performed based on Grasshof's Theorem motion characteristics.

The mechanism operates at predetermined speeds. The high speed activation and rapid cycle completion demands that the members of the operating mechanism to be safe, tough and durable to withstand stresses. The bending stress response of four bar links is analyzed using multi-body dynamics [2,3].

Scope of Work

The bending stress response of a four bar mechanism is analyzed by simulating links throughout complete cycle, using Flexible multi-body dynamic analysis software ADAMS and the results are compared with results from earlier analysis paper. After ascertaining the accuracy obtainable, the dynamic response of the four bar mechanism is analyzed for a scaled fabricated model.

Four Bar Mechanism Analysis

A four bar mechanism is considered to be basic mechanism for preliminary analysis to evaluate the

procedure to be applied for any complex mechanisms.

Figure 1: Four Bar Mechanism.

Figure 2: Four Bar Mechanism in ADAMS Software

The dimensions of the considered four bar mechanism is listed in below Table.

Table 1: Material and Geometric Properties of Four-Bar Mechanism

Parameter	Crank	Coupler	Follower
Length (cm)	10.80	27.94	27.05
Area(cm ²)	1.077	0.406	0.406
Area moment of inertia (cm ⁴)	1.66×10^{-2}	8.674×10^{-4}	8.674×10^{-4}
Modulus of Elasticity GPa	70	70	70

The crank is given an input speed of 340 rpm. The angular velocities of midpoint of coupler and follower links are plotted and compared with results from an earlier paper[2] as shown in Figs.

Figure 3: Angular Velocity Curves from Adams Software.

Figure 4: Theoretical Angular Velocity Curves (from Reference Paper#2)

Figure 5: Angular Acceleration Curves from Adams Software

Figure 6: Theoretical Angular Acceleration Curves (from Reference Paper#2)

BENDING STRESS ANALYSIS

The maximum top bending stresses in mechanism copular (link-3) and follower (link-4) are listed and at particular node the stress attains peak value shows the maximum bending stress. The peak rise shown in modal graphs. The two input motions are given as input at motion 1020deg/sec and motions 2040deg/sec. the processor applied to complicated mechanism for better analysis purpose.

VON MISES Hot Spots for PART_4_flex Date= 2015-04-11 16:11:26						
Model= MODEL_1		Analysis= Last_Run		Time = 0 to 0.356 sec		
Top 10 Hot Spots			Abs	Radius= 0.0 mm		
Hot Spot	Stress	Node	Time	Location wrt LPRF (mm)		
#	(newton/mm**2)	id	(sec)	X	Y	Z
1	29.1444	64	0.02848	219.071	130.634	-2.5
2	24.4325	51	0.02848	219.071	130.634	2.5
3	24.0935	49	0.02848	209.783	168.137	2.5
4	23.8502	67	0.02848	233.004	74.3793	-2.5
5	23.1642	24	0.02848	219.281	150.588	2.5
6	22.5734	48	0.02848	205.139	186.889	2.5
7	22.0134	62	0.02848	209.783	168.137	-2.5
8	21.5878	46	0.02848	195.851	224.392	2.5
9	21.3824	53	0.02848	228.359	93.1309	2.5
10	21.1099	63	0.02848	214.427	149.386	-2.5

Figure 7: Von Mises Stresses Table for Link-3 at Input Motion 1020deg/Sec

Figure 8: Von Mises Structural Bending Stress for Node-64, Link-3 At Input Motion 1020deg/Sec

VON MISES Hot Spots for PART_3_flex Date= 2015-04-11 16:11:26						
Model= MODEL_1		Analysis= Last_Run		Time = 0 to 0.356 sec		
Top 10 Hot Spots			Abs	Radius= 0.0 mm		
Hot Spot	Stress	Node	Time	Location wrt LPRF (mm)		
#	(newton/mm**2)	id	(sec)	X	Y	Z
1	22.2236	62	0.02848	129.181	95.448	-2.5
2	21.2276	49	0.02848	129.181	95.448	2.5
3	20.6587	48	0.02848	135.493	114.385	2.5
4	20.6329	63	0.02848	122.869	76.5113	-2.5
5	20.5879	52	0.02848	110.244	38.6377	2.5
6	19.7859	64	0.02848	116.556	57.5744	-2.5
7	19.3087	51	0.02848	116.556	57.5744	2.5
8	19.2942	65	0.02848	110.244	38.6377	-2.5
9	19.0054	50	0.02848	122.869	76.5113	2.5
10	18.6806	53	0.02848	103.932	19.7009	2.5

Figure 9: Von Mises Stresses Table for Link-4 at Input Motion 1020deg/Sec.

Figure 10: Von Mises Structural Bending Stress for Node-62, Link-4 at Input Motion 1020deg/Sec.

Figure 11: Required Input Power for Mechanism at 1020deg/Sec

VON MISES Hot Spots for PART_3_flex Date= 2015-04-11 16:02:59						
Model= .MODEL_1		Analysis= Last_Run		Time = 0 to 0.178 sec		
Top 10 Hot Spots			Abs	Radius= 0.0 mm		
Hot Spot	Stress	Node	Time	Location wrt LPRF (mm)		
#	(newton/mm**2)	id	(sec)	X	Y	Z
1	35.0072	65	0.01424	110.244	38.6377	-2.5
2	33.9637	52	0.01424	110.244	38.6377	2.5
3	32.893	64	0.01424	116.556	57.5744	-2.5
4	32.8713	66	0.01424	103.932	19.7009	-2.5
5	32.7298	27	0.01424	114.987	37.0565	-2.5
6	32.62	53	0.01424	103.932	19.7009	2.5
7	32.5398	14	0.01424	114.987	37.0565	2.5
8	32.1681	63	0.01424	122.869	76.5113	-2.5
9	32.1374	28	0.01424	121.3	55.9933	-2.5
10	32.0265	32	0.01424	146.549	131.74	-2.5

Figure 12: Von Mises Stresses Table for Link-3 at Input Motion 2040deg/Sec

Figure 13: Von Mises Structural Bending Stress for Node65, Link-3 at Input Motion 2040deg/Sec

VON MISES Hot Spots for PART_4_flex Date= 2015-04-11 16:02:59						
Model= .MODEL_1		Analysis= Last_Run		Time = 0 to 0.178 sec		
Top 10 Hot Spots			Abs	Radius= 0.0 mm		
Hot Spot	Stress	Node	Time	Location wrt LPRF (mm)		
#	(newton/mm**2)	id	(sec)	X	Y	Z
1	33.3581	46	0.01424	195.851	224.392	2.5
2	31.686	64	0.00356	219.071	130.634	-2.5
3	31.0179	48	0.01424	205.139	186.889	2.5
4	30.7875	49	0.01424	209.783	168.137	2.5
5	30.3045	47	0.01424	200.495	205.641	2.5
6	29.8821	61	0.01424	205.139	186.889	-2.5
7	29.3867	62	0.01424	209.783	168.137	-2.5
8	29.2315	60	0.01424	200.495	205.641	-2.5
9	29.1262	51	0.00356	219.071	130.634	2.5
10	28.2374	63	0.01424	214.427	149.386	-2.5

Figure 14: Von Mises Stresses Table for Link-4 at Input Motion 2040deg/Sec

Figure 15: Von Mises Structural Bending Stress for Node-46 Link-4 at Input Motion 2040deg/Sec

Figure 16: Required Input Power for Mechanism at 2040deg/Sec

RESULTS AND DISCUSSIONS

Stress Analysis of Four-Bar Mechanism

After assuring the kinematic parameters matched with the reference paper, it was further analyzed by using finite element method in ADAMS software, by making the links flexible. The input crank speeds applied is 1020 & 2040 rpm. The stresses produced in the coupler and follower links are tabulated in Table respectively. Also the maximum stress variation at one node in coupler and follower links during one revolution of crank is shown.

Table 2: Maximum Stresses on Coupler and Follower

Links	Speed (rpm)	Node Number	Von Mises Stress N/Mm ²	Speed (rpm)	Node Number	Von Mises Stress N/Mm ²
Coupler (link-3)	1020	64	29	2040	65	35
Follower (link-4)	1020	62	22	2040	46	33

CONCLUSIONS

- In this work, proceeding with validation of analysis procedure for the dynamic analysis of the four bar mechanism is observed to be appropriate for using Multi body dynamic analysis software ADAMS in the analysis of high speed four-bar mechanism.
- The four-bar mechanism which is considered to be operated at high speeds is analyzed and after checking the induced stresses in all the links of the mechanism during its operation, maximum stress is found as 35 N/mm² when it operates at 2040 deg/sec.
- It is concluded that if that mechanism operates beyond this high speed, the stresses induced may become more than the limiting values of the considered material, whose limiting value is about 35 N/mm², and hence it can be concluded that, the limiting speed of this particular mechanism is 2040 deg/sec.
- Also this work procedure can be extended to similar mechanisms to decide the limiting high operating speed beyond which when they are operated, produces the stresses beyond their limiting values. This work further can be extended by considering friction and damping effect in the analysis of mechanism.

REFERENCES

1. Fu-Chen Chen, Yih-Fong Tzeng, "On the dynamics of spring-type operating mechanism for 69 KV SF6 gas insulated circuit breaker in open operation", *Computers and Structures*, 80 (2002) 1715–1723
2. Vaidya.M and Padole P.M, "A Performance Evaluation of Four Bar Mechanism Considering Flexibility of Links and Joints Stiffness" *The Open Mechanical Engineering Journal*, 2010, 4, 16-24.
3. Amirouche FML. *Computational methods in multi-body dynamics*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc; 1992.
4. Greenwood DT. *Principles of dynamics*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc; 1988.
5. Anjaneyulu.J, VenkataRao.G, and Krishnamohan Rao.G "Theoretical And experimental Dynamic Analysis Of High Speed Mechanism Of A Switch Gear" *International Journal of Applied Engineering Research*, ISSN 0973-4562 Volume 10, Number 2 (2015) pp. 5271-5283, Research India Publications. <http://www.ripublication.com>.
6. Uicker Jr.J.J, Pennock.G.R, Shigley.J.E, *Theory of Machines and Mechanisms*, third ed., Oxford University Press, New York, 2003.
7. Ben Jonker, "Linearization Of Dynamic Equations Of Flexible Mechanisms-A Finite Element Approach" *international journal for numerical methods in engineering* vol.3.1, 1375- 1392 (1991).