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Problems and Result in Torsional Vibration Measuring and Analyzing on Marine Diesel Engine Propulsion

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Abstract:

This paper presents problems and result of measuring and analyzing torsional vibration on marine diesel engine propulsion shaft. Authors mocked–up, simulate for measuring and processing multinomial tortional vibration signal with interference or noise; error cycle prediction when extract sample in area of realtime and frequency. The results of this paper has deployed in case of normal firing and misfiring in a marine diesel engine.

Keywords: Torsional vibration on marine diesel engine propulsion; Interference and sampling errors of torsional vibration measurement; Fast Fourier Transform (FFT).

1. Introduction

Torsional vibration proplems arise simultaneously with intensive use of marine diesel engines for ship propulsion shaft. Calculating and measuring torsional vibration in marine diesel engine propulsion shaft must be stipulated in rules and regulation for the classification of ships by IACs (NK, ABS, Loyld, Veritas, DNV, Rusian Maritime Register,…).

We used the FFT Algorithm to process and analyze interference (noise) signals which come from speed encoder, air-fuel system, loading, operating conditions of engine or measuring device errors. Then show their important properties in area of realtime and frequency (Maximum, Minimum and Average values). In fact, there are many factors for measuring torsional vibration in marine diesel engine propulsion shaft line, even incase of diesel engine speed run rather stable, number of samples extracted for one working cycle of engine is alternator. Thus, error factor of extract sample is present and we need research to answer for questions:

- Does the measuring and processing torsional vibration signal error when extract sample error ?;
- How to overcome extract sample error when speed of diesel engine is variable ?.

That is the reason why this paper need be researched and found the results. During the research time, Authors mocked –up, simulated and programed on Matlab software tool when diesel engine fire normally and misfiring at one cylinder.

2. Error extract sample in measuring and processing torsional vibration signal

Extract sample error (sample rate) is consequence of set up configuration of collect sample error, the length of sample is not correct for one working cycle of diesel engine (include z cylinders). Ideal length of sample is covered seal for one working cycle of diesel engine, for 2 stroke engine, length is 360 degree of crankshaft angle and for 4 stroke engine is 720 degree of crankshaft angle.

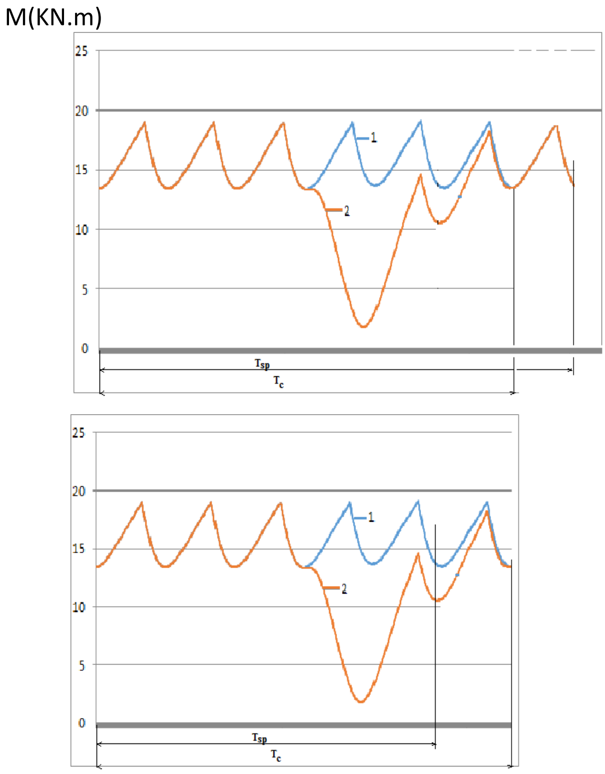

Fig 1. Extract sample for gas torque signal
Line 1: Total torque when engine is fire normally;
Line 2: Total torque when engine is misfiring at one cylinder.

Case (1): Extract sample cycle $T_{sp} > T_c$ or $f_{sp} < f_c$. In extract sample lenght N_{sp} = 1024 samples, $dt = 1/f_{sp} > dt_c = 1/f_c$ (s).
Case (2): Extract sample cycle $T_{sp} < T_c$ or $f_{sp} > f_c$. In extract sample lenght N_{sp} = 1024 samples, $dt = 1/f_{sp} < dt_c = 1/f_c$ (s).
$\mathbf{f_{sp}}$ = const and $\mathbf{N_{sp}}$ = 1024 samples.

In 2 stroke engine, MAN B&W 6S46 MC-C, at speed 120 rpm, if extract sample error when diesel engine speed is variable within ± 4 revolution per minute (rpm), that means a range diesel engine speed is 116 - 124 rpm, N_{sp} is collect sample quantity and extract sample rate is constant $\mathbf{f}_{sp}$ = 2048 sample/second.

n_E (rpm) is real speed of diesel engine;

Time for extract 01 sample is $dt_{sp} = 1/\mathbf{f}_{sp}$ = 4,8828E-04 (s) = 488,28μs;

Time for extract 2014 samples is T_{sp} (Sheet 1).

Example: n_E = 116 rpm, $\Delta\varphi = 360 *(60/n_E)/T_{sp}$, **Δφ = 372.4** Crankshaft degree (1.03 Cycle)

Table 1- Extract Sample Error when speed of diesel engine is variable

N (Sample)	n (rpm)	fE	dtE(s/cki)	dt_sp	f_s (Sample/sec)	phi_sp	chki_sp
1024	116	1.93	0.517	5.051E-04	2048	372.4	1.03
	118	1.97	0.508	4.966E-04		366.1	1.02
	120	2.00	0.500	4.883E-04		360.0	1.00
	122	2.03	0.492	4.803E-04		354.1	0.98
	124	2.07	0.484	4.725E-04		348.4	0.97

3. The matters of noise filter and torsional vibration signal forecast

In digital signal processing books, there are many other digital filters. We apply some digital filters to filter interference or noise out measured torsional vibration signal and to predict difference of signal when extract sample error happens.

The simulation results shown in figure 2 and figure 3.

(1)- Filtering interference out tortional vibration signal measured (Fig 2);

(2)- Predicting difference of torsional vibration signal when extract sample error happens (Fig 3).

After researching application of some filter in Matlab tool such as Traditional Filter and Adaptive filter. Output signal moves to one direction in the traditional filter so they is not suitable for our matter. On the contrary, the adaptive filter predicts signal for working cycle of diesel engine, gather data when lack or cut down data when redundant and re-calculate new value by linear interpolate method.

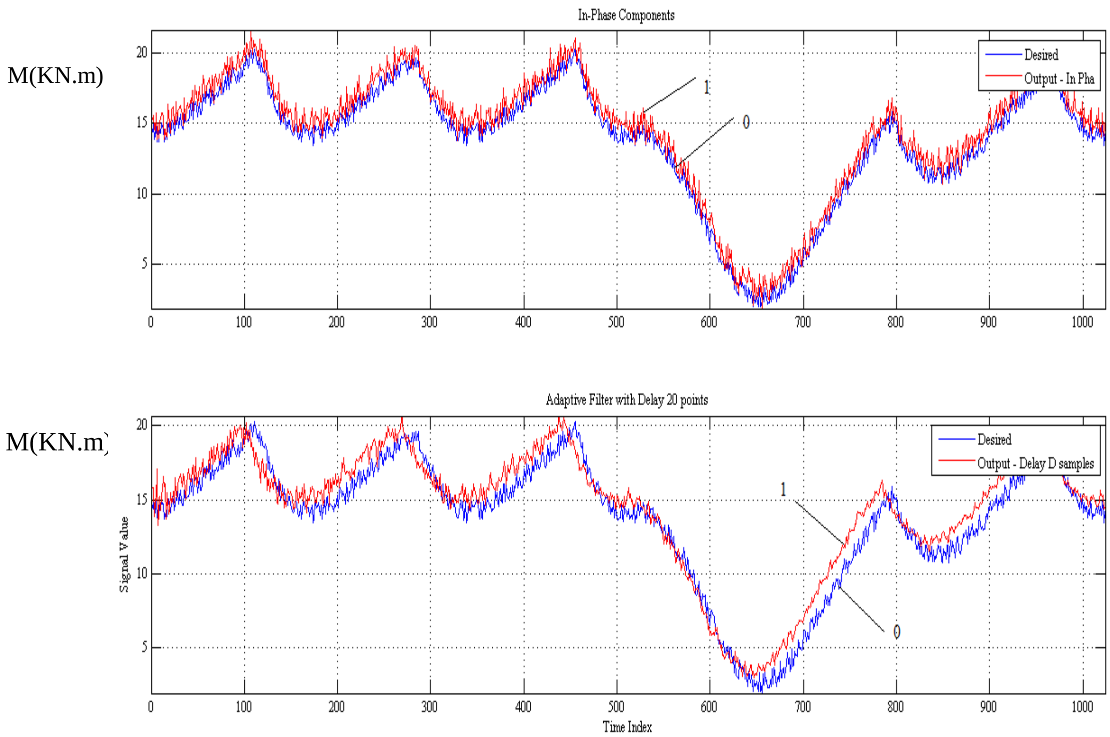

Fig 2. Torsional vibration signal simulation use the adaptive filter

Fig 2: Line 0 (blue) - Torque with interference;
Line 1 (red) - Torque with interference filtered

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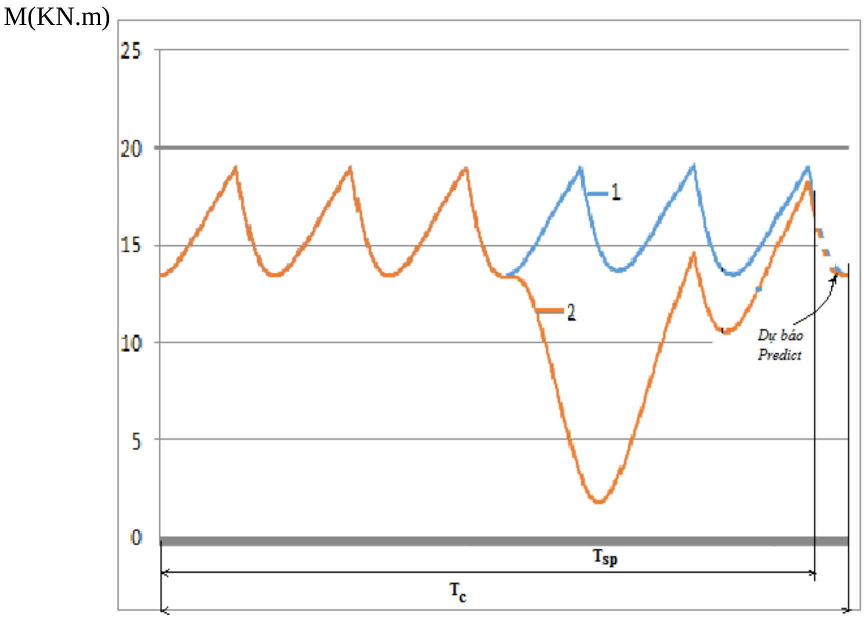

Fig 3. Torsional vibration signal prediction when extract sample cycle is shorter than diesel engine cycle

Fig 3: Line 1 (blue) - Torque when diesel engine work normally;
Line 2 (yellow) - Torque when engine is misfiring at one cylinder.
Continuous line: signal measured; Dash line: predict signal after measuring signal at continuous line.

4. Analysis of Results

In the table 2, when diesel engine works normally, in principle total torque contains main harmonics and secondary harmonic is zero. However, due to calculate error, to round in calculate process, random interference will exist so the amplitude vector will occur and secondary harmonic value is different zero. Extract sample error is lead to amended error for low grade harmonics that is hard to recognize easily. So we only consider to main harmonic (grade 6-H6) which is alternate wide and is easy to realize and estimate results shown in table 3.

Table 2. Simulation result for total torque Mo with 12 harmonics of amplitude vector R0 and phase 0, without interference, extract sample error, diesel NORMAL

R_0	**0.0775**	**0.0656**	**0.0531**	**0.0479**	**0.0504**	**2.3440**	**0.0170**	**0.0108**	**0.0116**	**0.0119**	**0.0185**	**0.5966**
n=116	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_c	0.1284	0.1878	0.1067	0.2377	0.4010	2.1746	0.5800	0.2768	0.1790	0.1695	0.2012	0.4779
R_0- R_c	-0.0509	-0.1221	-0.0536	-0.1898	-0.3507	0.1694	-0.5630	-0.2660	-0.1674	-0.1576	-0.1827	0.1187
n=118	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_c	0.0962	0.1395	0.0470	0.1504	0.2505	2.3094	0.2579	0.1341	0.0801	0.0867	0.1243	0.5651
R_0- R_c	-0.0187	-0.0739	0.0061	-0.1025	-0.2001	0.0345	-0.2409	-0.1232	-0.0685	-0.0748	-0.1058	0.0314
n=120	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_c	0.0775	0.0656	0.0531	0.0479	0.0504	2.3440	0.0170	0.0108	0.0116	0.0119	0.0185	0.5966
R_0- R_c	-0.0000	0.0000	-0.0000	0.0000	0.0000	0.0000	-0.0000	0.0000	-0.0000	-0.0000	0.0000	0.0000
n=122	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_c	0.1203	0.0322	0.1528	0.1363	0.2490	2.2941	0.1993	0.0922	0.0871	0.0845	0.1395	0.5544
R_0- R_c	-0.0428	0.0334	-0.0997	-0.0884	-0.1987	0.0498	-0.1823	-0.0814	-0.0755	-0.0726	-0.1210	0.0422
n=124	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_c	0.1592	0.0812	0.2253	0.2474	0.5217	2.1949	0.3561	0.1818	0.1488	0.1503	0.2866	0.4721
R_0- R_c	-0.0817	-0.0156	-0.1723	-0.1996	-0.4714	0.1490	-0.3391	-0.1710	-0.1372	-0.1384	-0.2681	0.1245

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Table 3. Main harmonic amptitude error (grade 6) of total torque Mo without interference, extract sample error, diesel normal

n(rpm)	116	118	120	122	124
dR(6)	0.219	0.062	0	0.022	0.090
dR(6)%	9.3%	2.6%	0.0%	0.9%	3.8%

Similar to consider total torque signal when engine work normal, random interference Arand = 1.5 (arround 9-10% compare with maximum torque). We consider for 2 main harmonics dR(6) and dR(12) with results as per table 4 and table 5 below:

Table 4 Simulation result for total torque Mo with 12 harmonics of amptitude vector R_0 and phase 0, interference Arand = 1.5, extract sample error, diesel NORMAL

R_0	**0.0775**	**0.0656**	**0.0531**	**0.0479**	**0.0504**	**2.3440**	**0.0170**	**0.0108**	**0.0116**	**0.0119**	**0.0185**	**0.5966**
n=116	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_c	**0.1342**	**0.2065**	**0.1140**	**0.2341**	**0.4251**	**2.1911**	**0.5842**	**0.2582**	**0.1861**	**0.1389**	**0.2438**	**0.4763**
R_0- R_c	**-0.0567**	**-0.1409**	**-0.0610**	**-0.1862**	**-0.3748**	**0.1528**	**-0.5672**	**-0.2473**	**-0.1746**	**-0.1269**	**-0.2253**	**0.1202**
n=118	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_c	**0.1059**	**0.1588**	**0.0548**	**0.1493**	**0.2739**	**2.3331**	**0.2610**	**0.1093**	**0.0814**	**0.0631**	**0.1549**	**0.5543**
R_0- R_c	**-0.0284**	**-0.0931**	**-0.0018**	**-0.1014**	**-0.2235**	**0.0108**	**-0.2440**	**-0.0985**	**-0.0699**	**-0.0512**	**-0.1364**	**0.0423**
n=120	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_c	**0.0775**	**0.0656**	**0.0531**	**0.0479**	**0.0504**	**2.3440**	**0.0170**	**0.0108**	**0.0116**	**0.0119**	**0.0185**	**0.5966**
R_0- R_c	**-0.0000**	**0.0000**	**-0.0000**	**0.0000**	**0.0000**	**0.0000**	**-0.0000**	**0.0000**	**-0.0000**	**-0.0000**	**0.0000**	**0.0000**
n=122	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_c	**0.0913**	**0.0846**	**0.0537**	**0.0543**	**0.0734**	**2.3724**	**0.0127**	**0.0155**	**0.0255**	**0.0414**	**0.0587**	**0.5819**
R_0- R_c	**-0.0138**	**-0.0189**	**-0.0007**	**-0.0065**	**-0.0230**	**-0.0284**	**0.0043**	**-0.0047**	**-0.0139**	**-0.0295**	**-0.0402**	**0.0147**
n=124	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_c	**0.1303**	**0.0239**	**0.1521**	**0.1393**	**0.2402**	**2.324**	**0.1989**	**0.1142**	**0.1006**	**0.0916**	**0.1755**	**0.5426**
R_0- R_c	**-0.0528**	**0.0417**	**-0.0991**	**-0.0915**	**-0.1898**	**0.0196**	**-0.1819**	**-0.1034**	**-0.0891**	**-0.0796**	**-0.1570**	**0.0540**

Table 5. Main harmonic amptitude error (grade 6 and grade 12) of total torque Mo with interference Arand = 1.5, extract sample error, diesel normal, R0(6) = 2.3440 kN, R0(12) = 0.5966 kN

n(rpm)	116	118	120	122	124
dR(6)	0.1528	0.0108	0	-0.028	0.020
dR(6)%	4.6%	0.3%	0.0%	-0.8%	0.6%
dR(12)	0.1262	0.0423	0	0.0147	0.0540
dR(12)%	21.2%	7.1%	0.0%	2.5%	9.1%

When signal with interference, error level dR(6) reduces than case of without interference. However, speed level is variable within ± 4 rpm, at node 1 (dR6), harmonic error is near 5%. On the contrary at node 2 (dR12) is 21.2%.

Finally, we researched on diesel engine in case of misfiring at one cylinder and the results shown the same in table 6.

Table 6. Simulation result for total torque Mo with 12 harmonics of amplitude vector R_{mf1} and phase mf1, interference Arand = 1.5, extract sample error, diesel misfire1

R_{MF1}	4.3275	2.7333	1.7725	1.3345	0.9192	1.8486	0.4560	0.3194	0.2347	0.1483	0.1180	0.5212
n=116	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_{MF1}- R_{MFC}	0.1494	0.0142	-0.1112	0.1937	-0.4066	0.2516	-0.0618	-0.1333	-0.1056	-0.0171	-0.1683	0.1468
dR%	3.45	0.52	-6.28	14.52	-44.24	13.61	-13.56	-41.72	-44.99	-11.53	-142.63	28.16
n=118	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_{MF1}- R_{MFC}	0.0778	0.0020	-0.0701	0.1166	-0.2366	0.0976	0.0475	-0.0430	-0.0459	0.0245	- 0.0742	0.0272
dR%	1.80	0.07	-3.95	8.74	-25.74	5.28	10.42	-13.45	-19.56	16.53	-62.90	5.22
n=120	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_{MFC}	-0.0053	-0.0195	-0.0074	0.0018	0.0004	0.0357	0.0034	-0.0079	-0.0066	0.0156	0.0341	-0.0340
R_{MF1}- R_{MFC}	-0.12	-0.71	-0.42	0.14	0.044	1.94	0.74	-2.464	-2.804	10.544	28.94	-6.55
n=122	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_{MF1}- R_{MFC}	-0.0914	-0.0492	0.0649	-0.1321	0.2774	0.0535	-0.0926	-0.0138	0.0093	-0.0436	0.0474	-0.0116
dR%	-2.11	-1.80	3.66	-9.90	30.18	2.89	-20.30	-4.31	3.95	-29.40	40.17	-2.22
n=124	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12
R_{MF1}- R_{MFC}	-0.1649	-0.0690	0.1151	-0.2448	0.5434	0.1154	-0.1713	-0.0612	0.0353	-0.1137	-0.0734	0.0702
dR%	-3.81	-2.52	6.49	-18.35	59.12	6.24	-37.57	-19.16	15.05	-76.64	-62.21	13.46

Base on data of table 6, we realized that the harmonic amptitude errors change with a large range even the diesel engine speed is not change (n = 120 rpm) ; the harmonic amptitude (H10) is 10.544% and the harmonic amptitude (H11) is 28.9%. The harmonic amptitude error at secondary harmonic is higher than at main harmonic (H6, H12) aslo when there is one misfiring cylinder on diesel engine.

5. Conclusion

This paper has outlined the use of Matlab software to simulate measuring and processing of torsional vibration signal and estimate the effect of interference and extract sample error incase of engine work normal and misfire.

Digital filters can be used to reduce the interference in the frequency modulater carry signal and predict geometric lenght of extract sample cycle.

REFERENCES

1. E.O Brigham, (1988) *The fast Fourier transform and its applications*; Prentice Hall Signal Processing Series, Englewood Cliffs, NJ
2. Đo Đuc Luu (*2009*). *Dynamic and Dianogtic marine diesel engine by vibration*. NXB. GTVT. Hà Nội.
3. Đo Đuc Luu *(2005*). *Một số vấn đề trong nghiên cứu, tính dao động xoắn hệ trục chính diesel lai chân vịt trên tàu thủy hiện đại*// Tạp chí GTVT. 2005. №10. Tr.32,33,62,63.
4. D.D.Luu, H.V.Si, L.V.Vang. (2014).*Quy chuẩn Việt Nam về dao động xoắn hệ trục diesel và ứng dụng xây dựng phần mềm tự động tính giới hạn xoắn các thành phần hệ trục diesel lai máy công tác*. Technology Science – Maritime Magazin, No 40, Maritime Pushlisher.
5. D.D.Luu, H.V.Si, L.V.Vang. (2014). *Virtual Instrument to automatically draw the permit maximum torsional pressures for the marine diesel shaft system*. Technology Science – Maritime Magazin, No 40, Maritime Pushlisher.
6. Nguyen Quoc Trung. (2006). *Digital Signal Processing and filter. Ha Noi Science and Technic Pulishing House*.
7. Matlab Tool USA, R2014a