eMARINA

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The Hong Kong Joint Branch of The Royal Institution of Naval Architects
and The Institute of Marine Engineering, Science and Technology,
and The Hong Kong Institute of Marine Technology
皇家造船師學會暨輪機工程及海事科技學會香港聯合分會
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HKJB & HKIMT Activities

The coronavirus COVID-19 pandemic had stormed the world this year! Lockdowns, social distancing and group gathering restrictions were in place world-wide to arrest it from spreading. Hong Kong as an international city had not been immune from its outbreak and its effects.

So far, even under the worst scenarios, a complete lockdown of the city has not been implemented. The border with the mainland, the port and the airport are partially closed. People may still travel to and from the city. However, these people are required to be medically tested for the virus and quarantined for 14 days. Despite all these measures, the city had experienced three waves of the virus outbreak. The statistics showed that these measures were effective! The number of people in the city affected by each wave of the infection was small if compared to its size and density of the population to other cities in the world. The relatively good results were due to the health and safety consciousness of the people in Hong Kong and the government's anti-pandemic efforts. People are required to wear masks while they are away from home. The number of people allowed to gather in public has also been reduced to four.

As academic bodies, the professionals in HKJB and HKIMT were very disciplined and health and safety conscious. They were willing to comply with the safety codes and measures to curb the spreading of the virus. All visits and seminars were therefore suspended since January 2020. Only one HKJB Council Meeting was held on 7 July 2020 after the city had no virus infection cases for many days and the gathering restriction had eased off!

Sadly, the publication of the eMARINA had to be suspended for the issues in March and June under the circumstances. Thanks to Mr. Jagmeet Singh Markkar. He had brought us back to life by sharing his article in the eMARINA! He had opened a new horizon for us to meet and discuss subjects of interest despite the restrictions in gatherings.

The end of the pandemic is nowhere in sight which means that seminars and visits cannot be organized in the near future! I would like to **appeal to all members to sending in their comments, views and articles to enrich the eMARINA in the coming months** so that the roles and functions of our societies continue to flourish under these difficult circumstances!

(Views from Editor)

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Members' Corner

Cropping of Propeller Blades

- A Case Study on "Effect on Engine Performance and Torsional Vibrations"

ABSTRACT

At times it may be essential to take remedial actions with due caution and deliberation even though that they may not be ideal. While keeping the 'commercial aspects and commitments' in mind, they may prove to be well calculated risks that are worth taking!

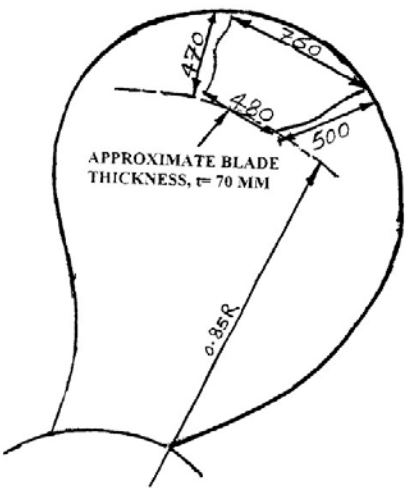
The discovery of a serious of cracks in one blade of the propeller when a vessel was at the repair berth at the end of a periodic repair while the Owners had no plan to dry dock the vessel and a very important commitment made to the Charterers for the delivery of the vessel on time, can be very challenging that may require such a remedial action.

Cracks had developed on one of the propeller blades. The cracks emanating from the propeller blade tips which radially inwards were at about 500 mm long and 760 mm apart. After the ends of the cracks were identified, the blades of the propeller were cropped to 0.797 of its original radius to fix the problem.

A "Torsional Vibration Analysis" was conducted before sailing to reassess the vibration characteristics of the vessel after the modification to identify the critical speeds of the vessel.

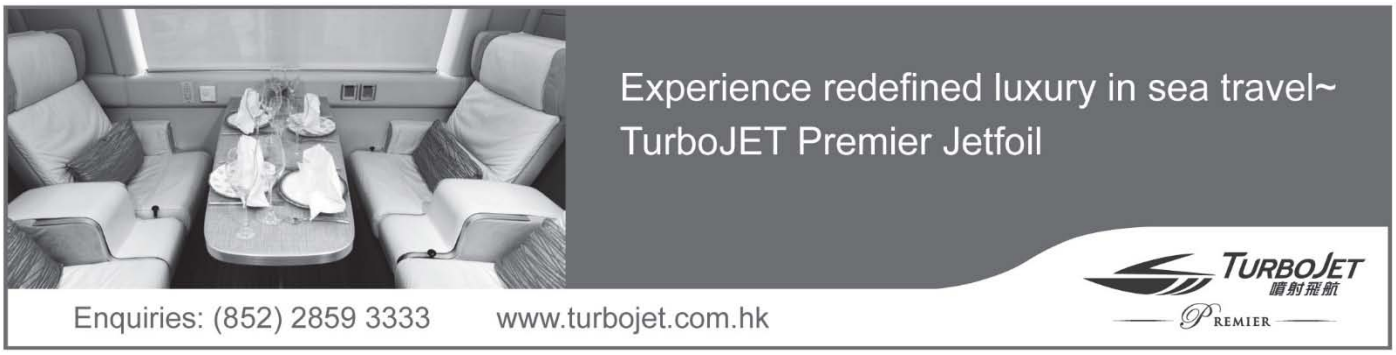
DISCOVERY

The vessel was undergoing repairs and carrying out inspections to complete a Special Survey alongside a shipyard berth with no schedule to dry dock. it was found during a routine propeller inspection by the Chief Engineer of the vessel that one of the propeller blades had two visible cracks emanating from the propeller blade tips and growing radially inward towards the center. These cracks were about 470mm and 500 mm long and 480mm to 760 mm apart.



THE CRACKS

Two cracks were found which propagated from the tip and growing radially inward towards the center of the propeller. The lengths of the cracks were 470mm and 500mm respectively. The crack had already open up gaps of about 2~2.5mm. Light could be seen through these gaps. The



appearance, location and size of the cracks were shown in the diagram.

CAUSE OF THE CRACKS

The blade profile was found to be smooth and the area between the cracks was also found to follow the natural profile of the blade. These were telltale signs that the cracks were not caused by mechanical impact/damage on the blades. The cracks appeared to propagate gradually over a period of time as the surface of the cracked area was found to have turned brownish and corroded. All the blades were then closely inspected and a thorough dye-penetrant test carried out on the tips of all the blades but did not reveal any more cracks.

In the absence of any mechanical impact or damage, these cracks were most probably associated with a previous repair about 7 months ago. Manganese Bronze propellers require careful heat treatment after any repair work in order to avoid lockup stresses which might cause stress corrosion in service. It was likely that this part of the propeller was not properly heat treated after the repair and lockup stress caused the cracks to develop over time.

OPTIONS TO REPAIR

The maker was requested to comment on a number of available options under the circumstances:

1. Drilling crack arresting holes at the root of the cracks and leave the blade as it was,
2. Carrying out “metalocking” to secure the crack section to the propeller blade
3. Cropping the cracked blade and the opposite blade and leaving it for repair till the next scheduled dry docking (more than 2 years away)

After considered the propagation pattern of the cracks and the extent of the damage, it was quite likely that leaving the propeller blade with only stress arresting holes drilled at the end of cracks or “metalocking” the cracks may result in the section between the cracks to break away during operations. This would cause excessive vibrations and an unnecessary and unpredictable emergency docking repair before the next drydock. The downtime as a result of such a disruption would be unacceptable and costly. As a result, the options to drill arresting holes at the root of the cracks and “metalocking” were dropped.

Cropping the tips of the cracked blade and the opposite blade instead of a permanent repair appeared to be the most viable solution to the problem. Advice from the maker of the propeller was sought on the effects of the cropping of the blades in the:

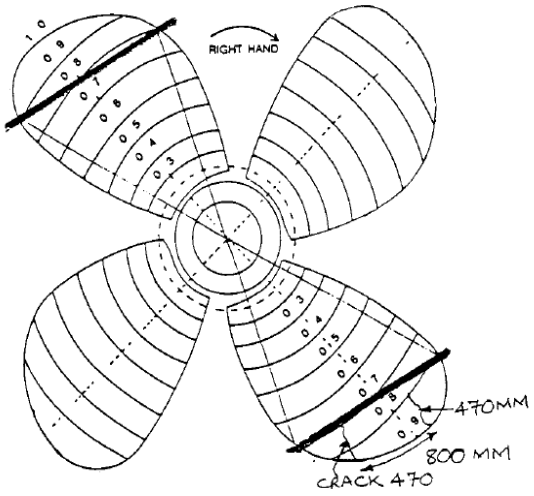
1. performance of the engine with regards to Power/Revolutions/Speed relationship.
2. probable changes to the vibration characteristics of the vessel

The feedbacks from the maker were very encouraging:

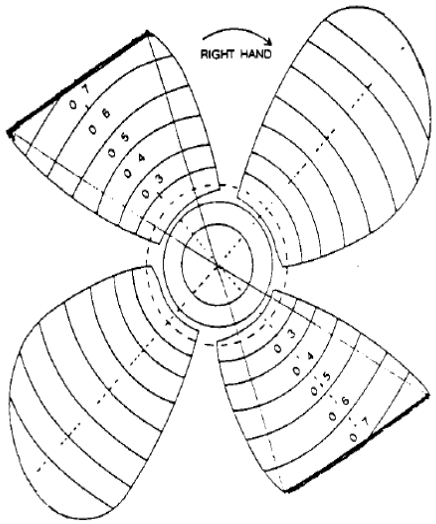
1. *"experience has shown that the effects upon the ship's performance are surprisingly small. For instance, the changes in the speed may be of the order of 0.1 knots and the increase in revolutions may be of the order of 3~5%"*
2. *"because the opposite blade is also to be cropped, there will be no static imbalance in the propeller. Although the cropped tips will perform differently in a hydrodynamic sense, experience has shown that this does not cause excessive or undue vibration. Indeed, we would fully expect that there will be virtually no change in the propeller's apparent performance"*
3. *"because the cropped tips no longer have a proper shape some cavitation effects will be experienced. This obviously limits the length of the time that a ship can continue in service but is something of an unknown quantity. However, it is known to have a quite a number of vessels to continue for 2~3 years in this condition with only minor cavitation damage which is rectified during the main repair.*

Based on these encouraging feedbacks, the decision to crop the cracked blade and the opposite blade was thus made. The cropped tip sections of the blades were sent back to the maker for the casting of new blade tips and made ready for their installation in the next dry docking repair.

The blades were cropped as per following dimensions:



CROPPED 70 (t) X 580 X 1805 MM



The following tables were the performance of the ship before and after cropping of the propeller blades:

PARAMETERS BEFORE CROPPING OF THE PROPELLER BLADES

	SHIP SPEED	AVG MEFO	RPM ME	RPM T/C	SEA TEMP	MAX EXH	MIN EXH	BEF T/C	AFT T/C	SCAV AIR	AIR OUT A/CLR	SCAV AIR
	Kn	mt			Deg C	Deg C	Deg C	Deg C	Deg C	Deg C	Deg C	Bar
	13.3	26.8	103.0	7,100	16	400	360	440	370	40	38	0.90
	13.0	27.6	104.4	7,000	18	405	345	460	400	40	40	0.80
	13.5	28.0	104.8	6,900	26	418	365	460	400	48	46	0.80
	13.5	28.0	105.5	6,900	24	415	360	470	405	45	45	0.80
	13.1	27.9	105.4	7,000	15	400	340	450	380	43	42	0.80
	12.4	27.6	104.2	6,900	14	400	345	450	390	40	39	0.80
	13.6	26.0	105.7	6,800	8	380	340	430	360	39	38	0.80
	14.0	23.8	103.7	6,500	18	370	340	415	365	36	35	0.70
	13.3	26.4	103.8	6,800	18	365	355	420	360	40	39	0.80
	12.7	26.4	102.7	6,500	16	380	360	430	380	40	39	0.70
	14.4	26.4	104.7	6,800	1	380	360	430	370	40	39	0.80
	14.1	22.3	101.0	5,800	22	400	370	440	385	39	39	0.60
	14.4	26.9	104.7	6,700	19	400	380	440	390	40	39	0.80
	14.1	27.3	105.5	6,900	18	400	380	450	390	40	40	0.80
	13.6	18.8	102.0	6,500	20	400	370	440	385	40	40	0.70
	14.7	22.3	101.5	5,800	19	400	370	435	390	39	37	0.60
	14.8	20.4	104.2	6,800	19	400	370	440	390	39	36	0.70
	14.1	25.9	104.5	6,700	12	400	380	430	380	39	37	0.80
	13.7	27.4	106.4	6,900	14	400	385	435	375	43	42	0.90
	13.7	26.9	105.3	6,800	14	390	380	425	375	40	38	0.80
	13.7	27.9	105.7	6,800	16	395	375	430	365	37	36	0.80
	13.8	22.8	101.5	6,000	13	380	360	430	390	40	40	0.60
	13.8	24.4	103.7	6,000	20	395	370	440	385	41	41	0.60
	13.6	24.8	103.4	6,200	22	405	380	450	400	42	42	0.60
	12.7	21.0	101.1	5,800	20	395	370	440	395	43	43	0.60
	13.7	24.1	102.0	6,200	10	380	360	420	370	40	40	0.70
	14.1	25.1	103.4	6,200	3	370	350	410	360	40	40	0.70
	13.4	27.4	106.8	6,600	12	385	360	425	372	35	35	0.80
	14.4	24.1	103.5	6,400	12	385	365	430	380	38	38	0.70
	13.0	26.3	103.6	6,200	20	395	370	430	390	33	33	0.70
	13.6	26.7	107.0	6,800	30	415	380	460	400	45	42	0.80
Average	**13.7**	**25.4**	**104.0**	**6,558**	**16**	**394**	**364**	**437**	**382**	**40**	**39**	**0.74**

RPM Range = 101 ~ 107

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PARAMETERS AFTER CROPPING OF THE PROPELLER BLADES

SHIP SPEED	AVG MEFO	RPM ME	RPM T/C	SEA TEMP	MAX EXH	MIN EXH	BEF T/C	AFT T/C	SCAV AIR	AIR OUT A/CLR	SCAV AIR
Kn	mt			Deg C	Deg C	Deg C	Deg C	Deg C	Deg C	Deg C	Bar
13.8	25.1	109.0	6,300	31	420	400	475	420	38	38	0.60
14.1	26.0	109.2	6,400	24	420	400	470	420	38	38	0.70
13.4	25.5	109.2	6,500	17	402	370	450	392	36	36	0.70
13.4	27.4	110.7	6,500	14	417	378	444	389	36	36	0.70
14.0	28.0	112.2	6,900	25	425	405	475	405	42	42	0.80
14.3	26.3	109.5	6,600	31	439	412	482	422	40	40	0.70
13.5	26.4	109.2	6,300	30	450	385	480	425	39	39	0.60
14.2	26.6	110.7	6,800	29	460	384	485	420	40	40	0.70
14.4	26.6	109.8	6,500	20	435	365	470	415	38	38	0.70
14.0	26.6	109.3	6,400	20	435	365	465	405	38	38	0.70
13.8	26.3	109.4	6,400	22	440	370	470	410	36	36	0.70
14.1	27.6	110.5	6,800	30	450	390	485	430	39	39	0.70
13.5	26.6	109.1	6,600	24	450	340	460	405	36	36	0.70
14.1	25.0	109.9	6,500	28	460	350	470	410	34	34	0.70
13.0	25.3	109.6	6,600	30	460	350	480	420	34	34	0.70
13.0	26.4	109.2	6,700	24	460	340	470	410	35	35	0.80
13.7	26.5	111.2	6,700	24	450	360	470	405	36	36	0.70
13.7	26.0	110.6	6,700	26	460	365	475	415	35	35	0.70
13.7	26.7	110.9	6,600	28	460	360	480	415	34	34	0.70
13.5	27.2	111.0	6,800	28	450	365	480	410	35	35	0.80
13.8	26.8	111.0	6,800	28	450	360	480	410	35	35	0.80
14.2	26.9	111.1	6,800	25	450	340	475	410	34	34	0.80
13.1	25.8	109.5	6,600	22	460	340	460	405	34	34	0.70
15.2	24.2	109.0	6,200	17	400	360	430	380	39	39	0.60
13.8	25.8	109.1	6,600	17	400	355	440	390	40	40	0.80
14.8	27.3	110.5	6,600	23	415	380	470	410	40	40	0.80
13.9	26.8	110.6	6,600	10	405	370	445	390	42	42	0.80
14.1	27.7	111.6	6,700	4	400	368	450	390	43	43	0.80
13.7	26.2	109.4	6,200	7	400	372	445	398	40	40	0.60
Average 13.9	**26.4**	**110.1**	**6,576**	**23**	**435**	**369**	**467**	**408**	**37**	**37**	**0.72**

RPM Range - 109 ~ 112

Parameters Before Cropping the Blades											
Average	**13.7**	**25.4**	**104.0**	**6558**	**16**	**394**	**364**	**437**	**382**	**40**	**39**	**0.74**
Parameters After Cropping the Blades											
Average	**13.9**	**26.4**	**110.1**	**6576**	**23**	**435**	**369**	**467**	**408**	**37**	**37**	**0.72**

		(A)	(B)
Increase in fuel consumption	%	***3.9***	***3.20***
Increase in RPM	%	***5.8***	***6.1***
Increase in Exhaust Temperature	%	***10.6***	***10.5***

(A) Values from day to day parameters
(B) Values when Indicator Cards are taken

CHARACTERISTICS OF THE SHIP AFTER CROPPING THE BLADES

Torsional Vibrations

It was expected that the vibration pattern of the vessel would be changed after the cropping of the two blades. The Chief Engineer was instructed to find out whether the vibration pattern of the vessel had

changed. After the vessel sailed out of the port, Chief Engineer confirmed that the vibration pattern had changed. The critical speed range recorded during the New Building Stage were no longer valid.

It was considered essential to find a reputable Classification Society approved company to carry out anew a "Torsional Vibration Analysis" for the vessel to re-establish the new vibration pattern of the vessel.

The analysis was carried out in fine weather conditions and calm sea. The rolling motions of the vessel were insignificant throughout the entire measurement period.

The following instruments were used in this new "Torsional Vibration Analysis:

1. RS 256-461 1000 pulse/rev Shaft Encoder
2. Scientific - Atlanta Model 2512, Calibrator
3. Scientific - Atlanta Model 2509, Signal Conditioner
4. Ono Sokki CF FFT Analyzer

All torsional vibration readings were measured in the angular velocity form i.e. degrees/sec. For comparison to the baseline data, all recorded signals were then digitally integrated to angular displacement (degree) units within the Analyzer.

In order to investigate the full torsional vibration characteristic of the vessel, measurements were taken with the engine speed from "Dead Slow" to "Maximum". Different intervals were also taken for different ranges of RPMs during the analysis:

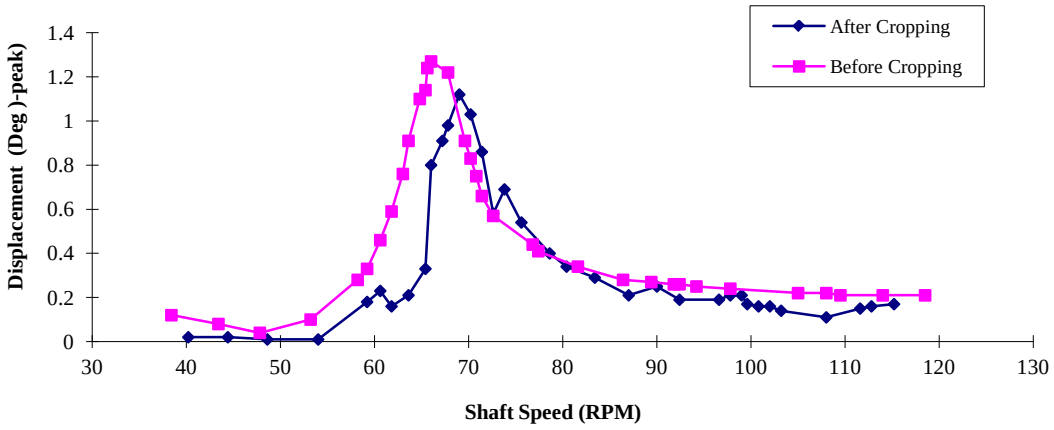
1. 40 ~ 60 RPM - readings were taken with 5 rpm interval.
2. 60 ~ 75 RPM - (Designed Critical RPM Range): readings were taken at 1 RPM interval.
3. 75 ~ 97 RPM - readings were taken at 3 RPM interval.
4. 97 ~ 103 RPM - readings were taken at 1 RPM interval.
5. 103 ~ 112 RPM - readings were taken at 5 RPM interval.
6. 112 ~ 114 RPM - readings were taken at 1 RPM interval.

Results

Under all measured shaft speeds, the fifth harmonics component was found to be dominating in the angular velocity spectra. In general, the torsional vibration amplitudes over the entire engine operating speed range had not varied significantly when compared to the data collected prior to the cropping of the blades.

However, it was evident from the following readings that the critical speed range has shifted from the previously 60 ~ 75 RPM range into the 65 ~ 80 RPM range. The new critical speed occurred at 69 RPM which was 4 RPM higher than the previous reading at 65 RPM.

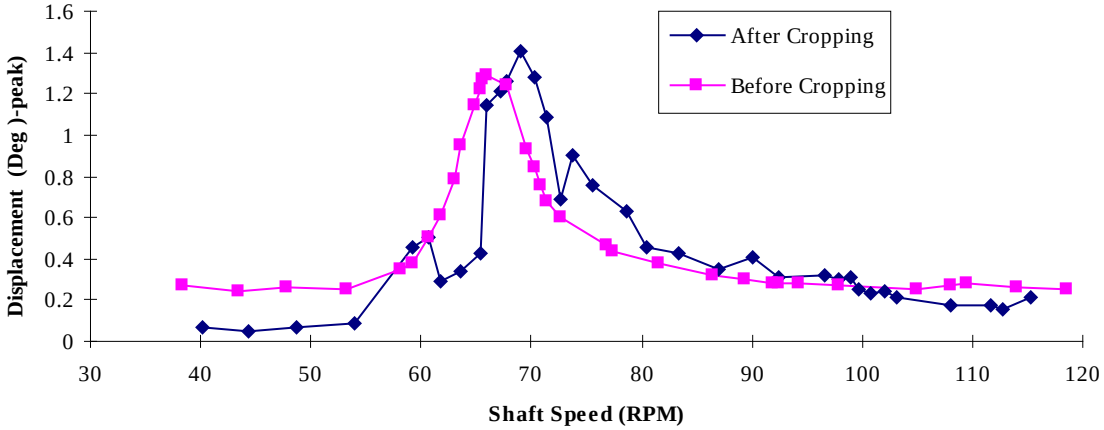
Torsional Vibrations - 5th order



This result tied in with the theory that cropping off propeller blade tips would effectively reduce the moment of inertia of the engine-propeller system while the torsional stiffness remains unchanged resulting in a shift of the torsional resonance i.e. the critical speed.

Despite the characteristic shift, only a marginal increase in overall-vibration levels occurred. A mild reduction of the fifth order component was also observed at the “new peak”. In addition, the torsional vibration levels remained almost unchanged outside the critical range i.e. below 60 RPM and above 80 RPM.

Torsional Vibrations - Overall



Hence as far as the Torsional Vibrations were concerned, no significant increase of overall-amplitudes had been observed within the newly discovered critical speed range. And vibration levels were also remained almost unchanged outside the critical speed range.

Linear Vibration Levels

Further vibration tests were performed to ascertain the effectiveness of the "Electric Vibration Damper" and to check the linear vibrations on the wheel house. Vibration levels in the fore-aft direction, in line with the imbalanced propelling forces was felt to be significantly higher. The "Electric Vibration Damper" reduces the engine shaft torsional vibrations significantly whilst it has no effect on the Wheel House deck linear vibration. Results showed that the second order shaft running frequency was critical and fell within the region of "Easily noticeable & Troublesome Threshold". *Further tests to identify "whether the hull vibration will cause any possible structural damages and/or induce body-fatigue to crew members" were recommended.*

Engine RPM

A comparative study was carried out between "RPM range the engine was operating prior to cropping of blades" to the "RPM range was operating after cropping of the blades". It was observed that the average RPM had increased from 101 ~ 107 to 109 ~ 112. The second range is the one during which engine operated with cropped blades. Thus, the increase in average RPM has been about 6% to deliver about the same load. The effect of increase in the RPM reflected in the higher exhaust temperatures and an increase in the specific fuel consumption. The variations in the parameters are as follows:

		(A)	(B)
Increase in fuel consumption	%	*3.9*	*3.20*
Increase in RPM	%	*5.8*	*6.1*
Increase in Exhaust Temperature	%	*10.6*	*10.5*

(A) Values from day to day parameters

(B) Values when Indicator Cards are taken

PHYSICAL INSPECTION RESULTS ON CROPPED PROPELLER

The propeller blades were closely examined (underwater) 9 months after the cropped propeller was put in service. The result was very satisfactory. There were some minor cavitation at a few isolated places. In general, the blades were free of any nicks and stress raisers at the tips. The cropped blades especially were found to be in very good condition.

CONCLUSION

The cropped propeller had performing well! It had not caused any undue torsional vibrations and adverse effect of concern on the engine performance. Some of the effects are summarized as follows:

1. The critical speed range has been shifted to a higher value i.e. from earlier range of 60 ~ 75 RPM to present range of 65 ~ 80 RPM.
2. The newly determined peak is occurring at 69 RPM, compared to earlier peak of 65 RPM.
3. No significant increase of overall-amplitudes has been observed within the newly discovered critical speed range and vibration levels have remained almost unchanged outside the critical speed range.
4. Second order shaft running frequency fell within the region of “Easily noticeable & Troublesome Threshold” and requires further tests to identify “whether the hull vibration will cause any possible structural damages and/or induce body-fatigue to crew members” .
5. For about the same Power/Ship speed, there has been an increase in following parameter values
   5.1 Fuel Consumption - by about 3.2%
   5.2 RPM - by about 6%
   5.3 Exhaust Temperature by about 10.5%
6. Peak Pressures fell by about 8%
7. Physical Inspections have not revealed serious cavitation and/or any further cracks.

Disclaimer: ***This article is presented purely from an academic point of view only and the author is not responsible for any loss or damage sustained by following the suggestions/views whatsoever presented in this article.***

***Mr. Jagmeet Singh Makkar, MSc, FICS, FRINA, FIMarE(I), FHKIArb, MCIArb, MHKMAG, AFIDRRMI**

Mr. Makkar is the Chairman of Maritime & Logistics Arbitration, Hong Kong Centre of International Commercial Arbitration and also a member in the Education & Training Committee of the Institute of Chartered Shipbrokers. His 30 plus years in the ship-management business had equipped him with the experiences in the conversions, new-buildings, sales & purchases, chartering and marketing of ships. Today, he is a Shipping and Energy Consultant, Educator and a Maritime Arbitrator.

(written by Mr. Jagmeet Singh Makkar)*

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