Development of a Torque Meter for Fishing Vessels*

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The paper describes the development of an electronic instrument to measure the torque developed on the propeller shaft of fishing vessels at various speeds of the propeller. By measuring the torque, it is possible to determine the actual power transmitted from the engine gear-box unit to the propeller so that propeller efficiency can be evaluated and the optimum size of the propeller for a specific engine and vessel can be determined.

The earlier devices used for torque measurement such as prony brake, rope brake and belt transmission dynamometer are mechanical devices. Next came the absorption dynamometers such as hydraulic and electric. The modern torque measuring devices are based on the use of a variety of transducers giving electric output which is processed in an electronic circuit. Such devices measure torque through shaft strain using appropriate transducers. They measure the twist on a length of shaft using transducers based on the variation of capacitance, resistance (strain gauge), reluctance etc. (Ettleman & Hoberman, 1963; Norton, 1969). A study of the various existing torque measuring devices reveals that they have one or more of the disadvantages such as the complexity in the construction of the transducer necessitating the use of sliprings and brushes using strain gauge transducers, non-linear response, slow response, low accuracy etc.

Practical considerations

Even though the size of the mechanised fishing vessels in India ranges from 7.6 m to 23 m, the most popular vessel is of 9.8 m and is selected for this study. 9.8 m vessels are powered with 40 hp engine, the rpm ranges from 1500 to 2000. The power transmission is done through reverse reduction gear box of gear ratio of either 3:1 or 4:1 so that the propeller shaft rpm is usually in the range of 300 to 600. The propeller is usually 3 bladed, made of manganese bronze or gun-metal fitted to strainless steel shaft and a mild steel intermediate shaft is also used as the transmission link between the propeller shaft and the gear box.

Working principles of the system developed

The principle adopted for the measurement of the torque transmitted by the intermediate shaft is the measurement of the twist in a fixed length of the shaft. This is based on the theory of torsion according to which when torque is transmitted by a shaft, it gets twisted and the angular difference between its ends is proportional to the torque, the shaft material remaining within its elastic limit. (Jenson & Chenoweth, 1975; Boresi *et al.*, 1975). The twist of the torque transmitting shaft can be found out from the relation.

$$Q = \frac{TL}{JG} \quad \text{radian}$$

$$= \frac{584\ TL}{Gd^4} \quad \text{degree, for solid shaft}$$

Where T = Tortional moment, Nmm

L = Length of shaft, mm

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J = Polar movement of inertia of cross sectional area about the axis of rotation, mm^4

G = tortional modulus of elasticity of the shaft, N/mm^2

d = diameter of the shaft, mm

It is estimated that the maximum torque transmitted by the intermediate shaft on the fishing vessel selected will not exceed 350,000 Nmm for a power transmission of 29.5 hp at the highest speed of the shaft, namely, 600 rpm. The torque angle, of the mild steel shaft of 40 mm diameter and 1000 mm length to transmit the above torque is 1°.

The transducer

The transducer was designed making use of an optical encoding disc made out of photographic print which has the advantage of reduced phase gitter. Fig. 1 shows the

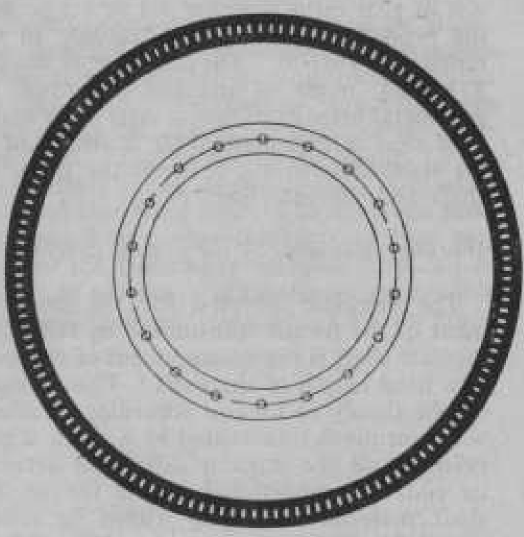

Fig. 1. Optical encoder disc

arrangement of the optical segments around the disc. Two such discs are firmly mounted

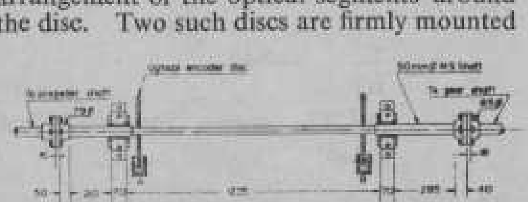

Fig. 2 Mechanical arrangement of transducer

on the shaft at 1000 mm apart and care was taken to align the segments to one another. Fig. 2 shows the arrangement of fixing the transducer disc on the shaft.

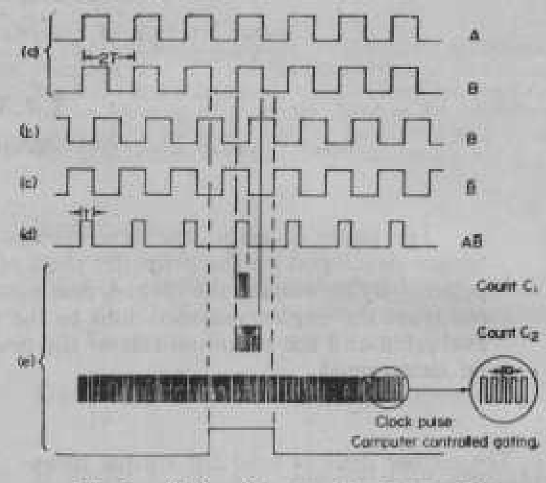

Fig. 3. Timing diagram of various pulses

The signal pickups A and B consist of photo transistors on one side and small lamps on the other side of the disc. The photo transistors are covered in such a way that they can be illuminated only by the beam of light falling on them from the lamp through the disc focused by a lens and the outside light will not have any effect on them. When the disc rotate the photo-transistors get illuminated intermittently and generate pulses of equal width as shown in Fig. 3. When the shaft is stationary, and when it is running the torque angle should be zero and hence there should be no phase difference between the pulses generated by the pickups A and B. This can be achieved by the adjustment of the pickups moving slightly to and fro, till the instrument reads zero torque.

When the shaft is transmitting power, it gets twisted at the load end and since the discs are firmly mounted on the shaft, the pulses generated by the pickup B gets delayed with respect to the pulses generated by the pickup A. Fig. 3 (b) shows the wave form generated by the pickup B when the shaft is transmitting power. Fig. 3 (c) shows the wave form $\bar{B}$, the inversed wave form of B and 3 (d) shows $A\bar{B}$, the phase difference between the signals A and B which represents the angular difference between the two transducer points on the shaft.

Signal processing

The functional block diagram of the signal processing is shown in Fig. 4. The pulse trains sensed from the optical encoders are

Fig. 4. Block diagram of signal processing

passed through schmitt triggers to get square pulses and are interfaced to a micro-computer which computes the torque and speed and displayed on an LED display. Fig. 5

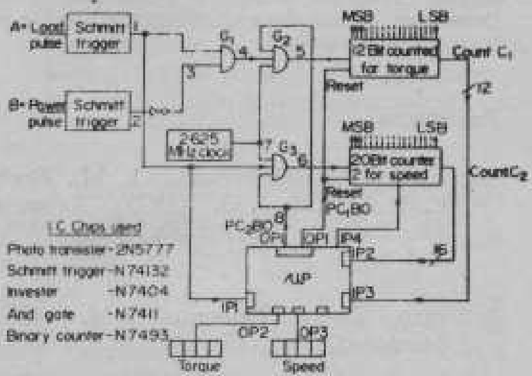

Fig. 5. Functional block diagram of the hardware

shows the functional block diagram of the hardware used.

The gate G1 outputs the pulse $A\overline{B}$ which is the phase difference between the pulses A and B which is also one of the inputs to the gate G2. The other inputs to G2 are a 2.625 MHZ clock pulse and a gating pulse from the micro-computer. The output of G2 is the input to a 12-bit binary counter reading the count C1. One of the transducer pulses, namely, A is the input to the third gate G3, the other inputs being the clock pulse and the gating pulse from the micro-computer. The output of G3 is the input to another counter of 16-bits which reads the count C2.

The binary counters are initially reset by the micro-computer and when the load pulse L (L=A) changes from logic HPGH to LOW, the gates G2 and G3 are enabled by the computer and both the counters start counting. The counting continues till a second change of logic stage from HIGH to LOW of pulse A takes place which is controlled by the computer and the gates are thus reset a few seconds after this second level change. Thus delay in resetting the gates is to avoid the possibility of errors in the counts. Fig. 3c shows the timing diagram of the clock pulse, gating pulse and the counts Cl and C2.

The count Cl in the 12 bit counter divided by the count C2 in the other 16 bit counter is proportional to the phase difference between the pulses A and B. Torque angle and thus the torque is calculated by multiplying the ratio $\frac{C1}{C2}$ with the appropriate constant through computer programming and the results displayed on LED display. The count C_2 is inversely proportional to the speed of the shaft and the actual values are calculated through computer programming and displayed.

Calibration of the instrument:

In order to calibrate the instrument, a scaled verifier experimental set up was designed with a shaft of smaller diameter and of shorter length. A shaft of 15 mm diameter was selected and the transducers were mounted on the shaft at 100 mm apart. To get a maximum torque angle of 1° on this shaft, the torque to be applied is 69,350 Nmm for a power transmission of 5.84 hp at the highest speed of the shaft at 600 rpm. Loading can be done on the shaft through a belt transmission arrangement. Fig. 6 shows the calibration set-up.

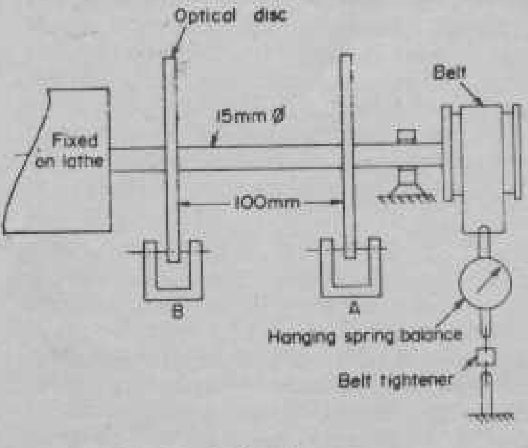

Fig. 6. Calibration set-up

By changing the gears, the speed of the shaft can be varied. The shaft torque was controlled by varying the tension in the friction belt of the brake. Since the full size transducers are mounted on the shaft of the calibration set up, the pulse trains picked up are exactly identical to those mounted on the full scale shaft. Hence the instrument's calibration is true for the full scale shaft also after multiplying the readings with the scale factor.

Performance tests:

The instrument was tested for its performance in the calibration set-up. The gear settings were changed to obtain different speeds of the shaft. Maintaining the shaft speed constant, the torque was varied from zero to the full value by varying the tension in the friction belt of the brake. Similarly the speed was varied from 300 to 600 rpm keeping the torque constant. It was observed that the response of the instrument was quite fast. The instrument could read very small torques and the response was found to be linear.

Results and conclusions:

A simple torque measuring instrument based on a known principle has been developed. The instrument has several meritorious features. No sliprings and brushes are required for collecting electric signals from the transducer and therefore the associated problems of contact noise and maintenance are absent. As a micro-computer has been used to process the signals the chip count has been reduced considerably. The response of the instrument has been quite fast and linear. As the full size transducer has been used in the calibration set up the pulse trains picked up are exactly identical to those mounted on the full scale shaft. Hence the instrument's calibration is true for full size shaft also after multiplying the reading with the scale factor which can easily be done through computer programming.

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