ELECTRIC DRIVE FOR BATTLE SHIPS

by Nikola Tesla

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The ideal simplicity of the induction motor, its perfect reversibility and other unique qualities render it eminently suitable for ship propulsion, and ever since I brought my system of power transmission to the attention of the profession through the American Institute of Electrical Engineers I have vigorously insisted on its application for that purpose. During many years the scheme was declared to be impracticable and I was assailed in a manner as vicious as incompetent. In 1900, when an article from me advocating the electric drive appeared in the Century Magazine, Marine Engineering pronounced the plan to be the "climax of asininity," and such was the fury aroused by my proposals that the editor of another technical periodical resigned and severed his connection rather than to allow the publication of some attacks.

A similar reception was accorded to my wireless boat repeatedly described in the Herald of 1898. The patents on these inventions have since expired and they are now common property. Meanwhile insane antagonism and ignorance have been replaced by helpful interest and appreciation of their value. Recently the Navy Department has let contracts aggregating $100,000,000 for the construction of seven war vessels with the induction motor drive, and an equal sum is appropriated to cover the cost of four huge battle cruisers which are to be fitted out in the same way. This latter project is resisted by some shipbuilders, turbine makers, electrical manufacturers and engineers who, in fear of a fatal mistake by the government and under the sway of patriotic motives, urged upon the authorities the employment of the geared turbine.

CONTROVERSIAL CORRESPONDENCE

Numerous letters of protest have been written to C. A. Swanson, of the Senate Naval Committee, but what has so far come out of this correspondence is purely controversial and of no profit whatever to those who seek information. It is regrettable that the question should have been raised at this critical moment, when speedy preparation against threatening national perils is recognized as imperative, and in view of this no doubt should be permitted to remain in the public mind as to the superiority of the equipment recommended by the naval experts. In the following I shall endeavor to make this clear to the general reader.

The most efficient means of propulsion is a jet of water expelled astern from the body of the vessel. Though the theoretical laws governing its action were precisely expressed fifty years ago by Rankine, a singular and inexplicable prejudice against this device still prevails among engineers and writers of text books on hydraulics. But the far sighted are keenly alive to its possibilities. While our present motive resources do not admit of an advantageous use of the jet, it can be confidently predicted that it will soon be instrumental in a more complete conquest of the deep. I firmly believe that at this writing it is being applied to the submarines devastating the oceans, for their silence alone can explain why they escape so easily detection by microphonic instruments. The sound emitted is the Achilles talon of the undersea boat. Its suppression materially increases the destructiveness of the new weapon.

THE HELICAL PROPELLER

However, under the existing conditions the best results are obtained in all kinds of surface craft with a helical propeller, which is operated in four different ways. First, straight from the shaft of the prime mover; second, by means of a gear wheel; third, through a hydraulic transformer, and, fourth, by an electric transmitter of power. As the screw in order to save energy must be revolved at a moderate rate, the first mentioned, or "direct drive," lends itself best to a reciprocating or rotary engine. The former is clumsy, the latter impossible, and competition has forced the turbine on the market. But, excessive speed being indispensable to its good performance, it had to be adapted to the propeller. This was, in a measure, accomplished by "staging" - that is, passing the steam through a number of turbines in succession - a plan obviously entailing great drawbacks, financial and otherwise. Need of reducing the bulk and cost of the machinery and insuring better working then compelled the adoption of the second arrangement - "geared turbine drive" - in which a peculiar pinioned wheel, first introduced by De Laval, transmits motion to the screw. Next, efforts to do away with certain limitations of this combination resulted in the third, or "hydraulic drive," the turbine actuating the propeller through a centrifugal pump and water motor. Finally, as the furthest step toward perfection, the last named disposition - "electric drive" - was resorted to. In this case the turbine imparts rotation to a dynamo, which in turn runs a motor carrying the screw on its shaft.

ADVANTAGES OF TYPES

Each of these forms has its supporters and champions. In principle the first would be the preferable were it not handicapped in many respects. The second type is cheap, but the gear is a serious objection. Though less

economical, the third commends itself by a number of practical and valuable features. As to the last, it is not only very efficient but obtains results impossible with other forms. The law of survival of the fittest is asserting itself, and the struggle for supremacy is now on between the geared turbine and the electric drive.

Through gradual improvement of the cutting tools, scientific design, metallurgical advances and refinement of lubricants, the so-called herringbone gear has been brought to great perfection. De Laval attained an efficiency of ninety-seven per cent and MacAlpine, Melville and Westinghouse ninety-eight and one-half per cent in the transmission from the driving to the driven shaft. On the other hand, ninety-three and three-quarters per cent may be considered as the maximum with electrical apparatus. This means that with the gear the same turbine would impart five per cent more power to the propeller, which should increase the speed of the cruiser from thirty-five to a little more than thirty-five and one-half knots. As it also appears at first sight that the electric drive requires additional space, is heavier and more costly, it is only natural for those who have not made a thorough study of all its phases to decide in favor of the gear.

SOME FATAL MISTAKES

But a careful inquiry into the subject would induce them to reverse their opinion. In estimating the relative merits of these essentially different propelling means they make two fatal mistakes. The first is to take the power transmitted under abnormal conditions as a criterion; the second to draw a parallel between instalments entirely unlike, one primitive, the other elaborate, the former being incapable of fulfilling important functions of the latter. When premises arc erroneous deductions therefrom must needs be faulty. Thus the opponents of the electric drive have been led to the conclusion that it is less efficient than- the gear, of greater weight, more expensive and uncertain of success. How much truth there is in these contentions will be apparent from an examination of well established facts.

The electric drive is of complex influence on results in ship operation. For the sake of brevity it will be viewed only in the following principal aspects: - (1) turbine performance, (2) power transmitted to the propeller, (3) efficiency of the screw, (4) low power cruising, (5) high power action, (6) fuel consumption by auxiliaries and apparatus for ship use, (7) general economy and (8) promptness and precision of control of all effects, internal and external.

The present turbines are extremely unsuitable for ship propulsion. They offer a striking example of an antiquated invention of small value elevated to a position of extraordinary commercial utility through profound research and astonishing mechanical skill. With hundreds of thousands of thin blades easily destroyed, buckets that through corrosion and erosion soon become wasteful and small clearances between surfaces rotating at terrific rates, they are a cause of constant danger and hazard.

IRREVERSIBLE TURBINES

But their cardinal defect is that they are irreversible, which necessitates the employment of separate turbines for backing. These, besides involving great expense and considerable friction loss, impose narrow limits on the temperature of the working medium. Very high superheat, so desirable in thermo-dynamic conversion, is out of the question in such, perishable structures, but from 200 to 300 degrees F. are permissible.

To that extent, then, the turbine is at an advantage when driving a dynamo. Two hundred degrees superheat will usually effect a saving of about twenty-three per cent of steam and ten per cent of fuel. This, however, is not the only gain. The turbine, freed from all the impediments of the gear drive, is capable of being safely run at a higher peripheral speed with a correspondingly increased efficiency and output. Thus, by moderate superheat and other simple and allowable expedients, it becomes practicable to develop twenty-five per cent more power from the same fuel, and this alone would make the electric drive decidedly superior to its competitor.

A MECHANICAL TOUR DE FORCE

As regards the power transmitted from the turbine to the propeller, it will seem in the light of the preceding that the gear is better by five per cent. That may be the case in exceptional tests, but it is quite different in actual service. To this is to be traced the error of those who are taking results obtained at constant load as standard of comparison. The perfection of the modern high speed gear was a veritable tour de force of the scientific machinist. It is a wonderful device, but it also has its inseparable weaknesses and shortcomings. Since the friction loss in it is sensibly constant through a wide range of performance, a relatively great amount of energy is absorbed at small load. The gear is likewise very sensitive to shocks and vibrations, which break down the capillary oil film, vital to smooth running. In consequence, there is great waste of power when the resisting force is subject to frequent and sudden fluctuations, Measurements I made with turbine gears have shown that while the efficiency with steady and normal effort was ninety-six per cent, not more than ninety per cent was realized with a rapidly varying load. This is what might be expected in practice. Any one who has listened to the tortured engines of a steamship in heavy sea could not have failed to observe how the turning effort varies as the vessel rolls, pitches and ploughs through billows and conflicting undercurrents. A similar state of things is apt to confront a war ship in action, as was evidenced in recent naval engagements, when mountains of water were raised by the exploding shells. Under such circumstances the gear is at a great disadvantage, as the electric drive is susceptible to these drawbacks in a much smaller degree. The idea that the gear transmits more of the primary power to the propeller than the combination of dynamo and motor is, therefore, largely illusionary. There is ample evidence, experimental and inferential, that rather the opposite is true.

SUPERIORITY OF ELECTRIC DRIVE

Considering the efficiency of the screw as distinct from that attained in the transmission of power, it is admittedly better with the electric drive, this conclusion being entirely based on the superior adaptability and flexibility of the system. But there are deeper causes which should be taken into account. The interposition of electromagnetic means between the turbine and propeller materially reduces the loss due to shocks, vibrations, racing and other disturbances owing to inherent elastic resilience and equalizing tendency. The saving of energy thus effected at high speed and in a heavy sea is considerable.

Economy in cruising is one of the most desirable qualities of a war vessel. This is its ordinary use, for the chance of ever being engaged in battle is remote. The bitterest opponents of the electric drive do not deny that it excels in this feature, upon which the manufacturer chiefly relies in guaranteeing a fuel consumption from 10 to 12 per cent smaller than with the gear. The latter is hopelessly condemned by inability of adjustment to varying speed and wasteful in cruising operations, while the former is readily adaptable and economical under all conditions.
Another quality of the electric drive, which may prove especially valuable in action, is its capacity of carrying great overload without danger, owing to the nature of the connection between the turbine and propeller, as explained. The gear is rigid and unyielding and any increase of effort, particularly if sudden, may cause a breakdown.

SAVING OF POWER
Referring to the auxiliaries proper and other apparatus for ship use, to which are chargeable approximately 20 per cent of the fuel consumed, a very substantial saving of power will be achieved through the introduction of the electrical method.

Quite apart from this central station supply will be operative in reducing other waste, many accessories will be dispensed with and general economy materially increased.

But from the military point of view the quickness, ease and precision of control will perhaps be the most significant of the advantages gained. Everything may be made to respond instantly to the pressure of a button. By reversing the motors the vessel may be brought from full speed to a stop within its length. It will be possible to make it go through all evolutions with extraordinary rapidity and a perfection of manoeuvre, undreamed of before, will be attained.
A curious mistake is made by the advocates of the turbine gear in estimating relative weight. It hardly needs be stated that it is unfair, if not absurd, to compare arrangements of widely different character and scope. Only such as are capable of accomplishing the same results should be considered. Now, a gear drive corresponding to the electric would consist of four main turbines with gears, four reversing turbines of the same capacity, and eight smaller driving and reversing turbines for cruising. This agglomeration of complex and not all too rugged machinery, with its network of water, air and oil pipes, valves, pumps and attachments, would by far exceed in weight the proposed electric drive, and would also require better structural protection, not to speak of other defects and shortcomings.

QUESTION OF WEIGHT
It should be observed, however, that the weights must be taken in their relation to that of the ship. One equipment may be heavier than another, but if it is more efficient and thereby reduces the weight of fuel and other cargo, it is for all purposes the lighter of the two.

The same is true of the cost. Comparative figures mean nothing. The question is whether the investment of capital is justified by what is to be accomplished. But enough has been said to show that for results in all respects equivalent, assuming them to be possible, the gear type, notwithstanding all claims to the contrary, would be more expensive.
That the electric drive is experimental and uncertain of performance is the least tenable of adverse assertions. In the first place, it has been successfully employed on a number of vessels and a great many more are being built. It also was found to be capable of an efficiency higher than that of any other form. But this is quite immaterial. The confidence that in the present instance all expectations will be realized is not based on a few demonstrations, but on years of experience with power plants ever since my system was commercially inaugurated. Tens of millions of horse power of induction motors are now in use the world over and no failure is recorded.

NEW CRUISERS' REQUIREMENTS
The new cruisers will require 180,000 horse power each, which, if necessary can be developed by four units of 45,000 horse power. Turbines of that capacity have been constructed and are in operation today. Dynamos of corresponding output have been installed at several places and are supplying light and power to large cities and districts. Induction motors of 15,000 horse power are being turned out by the manufacturers and can be produced in any size that may be desired, for of all kinds of motors this is the simplest and most dependable. Long since the whole system has been worked out and perfected to the least detail. The project is colossal, but it can be readily carried out by any of the few concerns who are possessed of the proper facilities. Not even a new tool has to be made. There is nothing whatever untried or hazardous about the electric drive.

Much stress is laid on reports, still to be verified, that it was rejected by England and Germany. But this is of no consequence. It has been rejected here more than once. Besides, there was war in the air of Europe and the time for radical innovations unpropitious. Moreover, the Diesel engine was looming up with large possibilities and Dr. Föttinger's hydraulic drive was being tried. The beginning must be made somewhere and it would be deplorable indeed if the United States, where the invention was first announced and introduced on a gigantic scale, were the last to recognize it. Such mistakes have happened only too often. The foreign navies are not in the habit of keeping the press informed of their doings and it is safe to predict that if progress in this country is much retarded there will be a repetition of previous disappointments.

It is unnecessary to dwell on other objections which are of minor importance and of no bearing on the principle. Without going into tedious technical discussion, it may be stated that the electric drive, if judiciously designed, will save not less than twenty-five per cent of fuel and, with due regard to this and certain specific and invaluable advantages, will be lighter, cheaper and in every respect more dependable than the gear. In fact, I believe that a scheme can be devised permitting the placing of all vital parts below the water line. In view of this, it is to be hoped that the Secretary of the Navy will not pay attention to the protests of rivals, however patriotic, but will cause the good work to be pushed

to completion with all the power at his command.

These statements are to be understood as reflecting the present state of the art. The advent of a reversible turbine will profoundly affect the situation in favor of the gear. Such a machine has been perfected and was described in the Herald of October 15, 1911. It is the lightest prime mover ever produced and can be operated without trouble at red heat, thereby obtaining a very high economy in the transformation of heat energy.. I anticipate its speedy and extensive application to ship propulsion. But although an ideally simple and very inexpensive drive will be thus provided, there will still be weighty reasons for adopting the electric method on war ships. In order to dissipate all doubt created in the mind by diversified engineering opinion, I will make known but One of them, which in itself is sufficiently consequential and convincing to dispense with further arguments.

DISARMAMENT IMPOSSIBLE

It is idle to dream of disarmament and universal peace in the face of the terrible events which are now unfolding. They prove conclusively that no country will be allowed to control all others by any means. Before all peoples can feel secure of their national existence and worldwide harmony established certain obstacles will have to be removed, the chief of which are German militarism, British domination of the seas, the rising tide of Russian millions, the yellow peril and the money power of America. These adjustments will be slow and pennible in conformity with natural laws. International friction and armed conflict will not be banished from the earth for a long period to come. The drag on human progress would not be so great if war energy could be maintained in purely potential form. This can and will be done through the universal introduction of wireless power. Then all destructive energy will be obtained without effort merely by controlling the life sustaining forces of peace.

The maintenance of war ships and other military implements involves an appalling waste. A vessel costing twenty millions of dollars is rendered virtually worthless in the short span of ten years, deteriorating at the mean rate of two million dollars a year, interest not considered. Hardly more than one out of fifty serves its real purpose. To lessen this ruinous loss and exploit certain inventions I elaborated a scheme some years ago. It was recognized as rational bur financially and in other ways difficult of realization. Now, when national economy and preparedness have become burning questions, it assumes special import and significance.

TO USE WAR SHIPS IN PEACE

The underlying idea is to make war ships available for purposes of peace in a profitable manner, at the same time improving them in a number of features. I am aware of the proposal lately advanced to employ them as carriers of commerce, but this is not feasible and would be an impediment to further perfection. My project primarily contemplated the installment of the electric drive and the use of the turbo-dynamos for light and power supply and manufacture of various valuable products and articles aboard or on land. This would be a step in the direction of present development meeting the objects of both military and industrial preparedness. I further intended the creation of a type of vessel on radically different principles, which would be a precious asset in peace and ever so much more destructive in war. The new cruisers, if equipped as planned by the Navy Department, will constitute four floating central stations of 180,000 horse power each. The turbines and dynamos are designed for highest efficiency and operate under most favorable conditions. The power they are capable of developing represents a market value of several million dollars a year and could be advantageously utilized at places where fuel can be readily obtained and transport is convenient. The plants would also prove of great value in cases of emergency. They could be quickly sent to any point along the coast of the United States or elsewhere and would enable the government to lend speedy assistance whenever necessary.

But this is not all. There is another and still more potent reason for adopting the electric method. It is founded on the knowledge that at a time not distant the present means and methods of warfare will be revolutionized through novel applications of electric force.

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