SCREW-PROPELLERS, THEIR SHAFTS AND FITTINGS.

[The Engineer.]

SCREW-PROPELLERS, THEIR SHAFTS AND FITTINGS.

By HAMILTON W. PENDRED.

THE grand aim of all inventors who have dealt with the screw has been, of course, to increase its efficiency ; it would be quite beside the purport of this paper to refer in detail to what has been done years ago in this matter ; the author, it will be remembered, is dealing with recent practice, and with it only. The labors of recent inventors have been devoted to reducing vibration, and obtaining a greater thrust per indicated horse-power than is available with the common screw ; they may not themselves realize this truth, but the fact remains that the screw which gives the greatest thrust for the least expenditure of power is—other things being equal—the best. No one has addressed himself within the last few years with more success, perhaps, to increasing the efficiency of the screw than Mr. Robert Griffiths. His attention was first directed to the screw-propeller on witnessing some experiments made by Captain Ericsson on the Regent's Canal about thirty-five years ago, and he began his own experiments about ten years later. His first idea was to find out what portion of the screw's disc was most effective—in other words, the relation of the outside of the disc to the in-

ner portion. He decided to fill up the central portion with a sphere, anticipating a certain calculable loss, but instead of loss he had a slight gain in speed. Working this out experimentally, he found the best size of sphere to be between a quarter and one third the diameter of the screw. Experimenting then on the shape of the blades, he found that the width of the blades just over the sphere should be equal to one third the diameter of the screw, and at the points one ninth thereof, with a movable-bladed screw he found that when the pitch was set to equal $1\frac{1}{4}$ diameters, the water had no tendency either to increase or diminish the pitch, but that when set coarser the water tended to increase that coarseness, and when set finer the water tended to increase that fineness. The author would draw attention to this as a point in the science of the screw-propeller worthy of notice. A screw-propeller occupies an intermediate position between a disc and a paddle-wheel; if the pitch of a screw were reduced to the minimum, then it would be merely a disc; if, on the other hand, it had a maximum pitch, so to speak, it would become a paddle-wheel, and would tend to turn the ship round and round on her centre, because of the difference of density of water above and below the centre of the shaft. It seems then to the author that any screw acts to some extent as a paddle-wheel, and must tend to give a ship what sailors call a port or starboard helm, and that a fine pitch must be the best, while if area be wanting, it is better to get it by multiplying

the number of the blades rather than by adding to their length.

Mr. Griffiths has latterly advanced certain views respecting the mode of fitting screw-propellers. He advocates, first, the inclosing of the screw within a tube-like case or shield, to which the water coming to the screw can only obtain access from below; the diagram No. 1 shows the arrangement. The author will not enlarge on the scheme; it is one which has provoked much controversy. Mr. Griffiths claims, as regards the inclosure of the screw, that the water is more equally fed to the screw, more closely confined to it, and is led from it in such a direction as is best calculated to economize the engine power and give the best working results. He also claims that the inclosing of the screw protects it from fouling and from danger of fracture. Mr. Griffiths likewise advocates the duplication of screws, not on the ordinary twin principle, but in the manner shown in diagram No. 2, one screw being placed in the head and another at the stern of the vessel.

In a paper which Mr. Griffiths read before the Institution of Naval Architects, he stated that his attention was first drawn to the necessity of having bow and stern screws, from the danger attending the use of the long steamers now employed, that danger being increased by making the safety of the ship dependent on a single set of machinery, an arrangement also that increases the difficulty of constructing machinery, owing to the immense castings and forgings necessary

to develop the great engine-power demanded to secure high speed. The opponents of the shield-tube aver that while the screw has less chance of becoming fouled, should it become fouled it would be infinitely more difficult to clear than an uncovered screw. As regards the use of the tunnel as a water-feeder to the screw, Mr. Griffiths cites the case of the Dwarf, which, with a speed at first of about 9 knots, was subsequently reduced to about $3\frac{1}{2}$ by planking up the after-run of the vessel; this result he attributes solely to the circumstance that the alteration of lines obstructed the flow of water to the screw.

In a second paper, Mr. Griffiths stated that, in the course of experiments with a model, he found that when he divided the power and applied one half to the stern and another to the bow-screw, each screw being inclosed within a tunnel, the speed of the model was increased nearly as the square root of the power, but when the power was doubled alone on the bow or stern screw, then the increase of speed was only as the cube root of the power. The way Mr. Griffiths accounts for this is that a better water supply reaches the screw.

Having said so much of a particular and important innovation in existing practice in screw propulsion, the author will now proceed to say a little about the nature of that practice, as carried out by the best firms in the present day. The diagrams illustrate a somewhat singular diversity of practice amongst engineers, the various screws varying greatly from each other, both in the shape and proportion of their blades and the number of blades forming each.

Diagram No. 3 illustrates a three-bladed screw, fitted to H.M.S. Lapwing by Messrs. Rennie. The diameter of this

to Alexandria, and the hourly consumption of coal was 34 cwt. 9 qr. 9 lb.; mean speed, 10.69 knots.

Trials of the Charkieh with a six-bladed propeller and a three-bladed propeller:

Kind of Screw.	Consumption of coal per hour.	Mean speed.
6-bladed	33 cwt. 3 qr. 15 lb.	10.65 knots.
3-bladed	34 cwt. 0 qr. 9 lb.	10.69 knots.

The six-bladed propeller, however, caused the least vibration. The following table shows the comparative particulars of this vessel with a six-bladed propeller and those of the steamship Ruahine:

Charkieh and Ruahine.

Name of ship.	Displacement in tons.	Area of midship section in square feet.	Indicated horse-power.	I.H.P.	Displacement in tons.	Area of midship section in square feet.	Indicated horse-power.	I.H.P.	Speed in knots per hour.	Area of mid-section in square feet.	Total area of propelling surface in square feet.	Speed $3 \times$ mid-section I.H.P.	Speed $3 \times 3 \sqrt{\text{displacement}}$ I.H.P.
Charkieh...	2200	462	1475	3.192	1.491	11.4	8.105	459.3	0	169.19			
Ruahine....	1850	424	1540	3.632	1.2	13	10.408	604.88		215.4

FIG. 17.

screw is 8 ft. 6 in., the pitch varying from 9 ft. 6 in. to 13 ft. 6 in. This screw is a fair example of a Griffiths three-bladed propeller, and was designed to comply with those conditions discovered by Mr. Griffiths as regulating the most efficient action of his propeller. It has a boss, which tapers outwards, and the blades are slightly curved forward, the pitch of the screw is uniform. The nominal horse-power of the Lapwing's engines was 80, the indicated power 502, or 6.25 times the nominal; the diameter of the propeller was $3\frac{1}{2}$ times that of the boss.

Diagram No. 4 illustrates a double two-bladed Mangin screw, fitted to H.M.S. Bullfinch. It is 7 ft. 3 in. in diameter, pitch uniform; nominal horse-power of engines, 80; indicated horse-power, 458.5; or about $5\frac{1}{2}$ the nominal. This form of screw is frequently made with a varying pitch, and is also made as shown in diagram No. 5, which is a more modern form than that of the screw of the Bullfinch. In February, 1868, H.M.S. Blanche was officially tried, being fitted with a Mangin screw; diameter, 14 ft. 7 in.; pitch of the leading portion of the blade, 15 ft. 7 in., and of the trailing portion 17 ft.; the mean length of blade on keel line being 12 ft. The speed of the ship was 13.631 knots an hour, the screw making 88 $\frac{1}{2}$ revolutions with full boiler power; half boiler power gave 11.78 knots. The official report stated that the use of full power created a heavy thumping action upon the ship's stern, the same action being very marked during comparative trials with the Shannon about ten years ago.

Diagram No. 6 illustrates a common two-bladed screw by Messrs. James Watt & Co., 16 ft. in diameter and 20 ft. pitch; length of blade on keel line, 3 ft. 4 in.; indicated horse-power of engines, 458. A propeller of this kind, provided with lifting gear, was fitted to H.M. troop-ship Simoom.

FIG. 16.

Diagram No. 7 illustrates a two-bladed Griffiths propeller fitted to H.M.S. Collingwood by Messrs. Rennie. The author is not in possession of any particulars of its performance.

Diagram No. 8 represents a six-bladed screw having a diameter of 15 ft. 9 in., and a pitch varying from 17 ft. 6 in. to 21 ft. 6 in., fitted to the Egyptian Government steamer Charkieh, and the theory of its action was, that by subdividing the surface of the blades into many parts, a greater uniformity of action results; but comparative experiments with this and a three-bladed screw demonstrates that little advantage rested with either. The first-named screw was used from Malta to Alexandria; the latter screw was used from Venice

Diagram 10 illustrates the propeller of the latter vessel. Diagram No. 9 represents the two-bladed Griffiths screw fitted by Messrs. Maudslay to H.M.S. Lord Warden and Lord Clyde, which are sister ships. The diameter of the screws is 23 ft.; mean pitch, 23 ft. 6 in., varying from 21 ft. to 26 ft.; the indicated horse-power of the engines is 6705; number of screw revolutions, 63.3; speed of ship, 13.49; displacement, 9000 tons.

The following table shows the relative performances of H.M.S.'s Minotaur, Agincourt, and Bellerophon.

Minotaur, Agincourt, and Bellerophon.

Name of ship.	Displacement in tons.	Area of mid-section in square feet.	Indicated horse-power.	I.H.P.	Area of mid-section in square feet.	Displacement in tons.	I.H.P.	Speed in knots per hour.	Area of mid-section in square feet.	Total area of propelling surface in square feet.	Speed $3 \times$ mid-section I.H.P.	Speed $3 \times 3 \sqrt{\text{displacement}}$ I.H.P.
H.M.S.												
Minotaur....	10275	1322	6193	4.684	1.659	14.16	9.713	606.71	216.616			
Agincourt....	9000	1187	6867	5.785	1.310	15.43	8.600	635.38	231.242			
Bellerophon..	7369	1207	6199	5.135	1.181	14.05	—	540.37	169.229			

The next propeller to which the author would direct attention is the Lowe-Vansittart, and Table No. 7 shows the performance of this screw as contrasted with the Griffiths, fitted to the same vessel, the Scandinavian, while Table No. 8 shows the results attained with H.M.S. Druid. With the former vessel it was found that the speed attained while using the Griffith four-bladed screw, diagram No. 10A, was 11 $\frac{1}{2}$ knots, while with the Vansittart screw, diagram No. 10B, the speed was 12 knots, the indicated horse-power being equal in both cases. Each screw had four blades and was 25 ft. pitch.

VANSITTART TABLE.

SS. Scandinavian, Liverpool to Montreal and back.—Registered tonnage, 1811.											
Nominal H. P.	400	400									
Indicated ditto, average	1800	1800									
Number of revolutions	54	47 $\frac{1}{2}$									
Steam pressure	30 lb.	30 lb.									
Average speed, knots	11 $\frac{1}{2}$	12									
Displacement	5375 tons	5375 tons									
Diameter of propeller	18 ft.	18 ft.									
Pitch of ditto	25 ft.	25 ft.									
Description of ditto	Griffiths	Lowe-Vansittart									
Number of blades, steel	4	4									

H. M. S. Druid, 350 H.P.

Immersed mid-section, in square feet	413.3	413.3
Revolutions per minute, mean	96.8	95.03
Indicated H.P.	2373.74	2271.71
Speed of ship, knots	12.986	13.064
Speed $3 \times$ mid-section, I.H.P.	381.3	403.0
Description of propeller	Griffiths	Lowe-Vansittart
Slip per cent.	10.37	8.01
Number of blades	2	2, gunmetal

Henrietta Vansittart.

Place of trial, Maplin Sands, on measured mile, by order of the Admiralty, December, 1869.

A trial was made in Stokes Bay with H. M.'s gunboat Fancy, to test the Vansittart and the common screw, and it was observed that there was an almost total absence of vibration when the former was used. The reversing of the propeller backed the boat in a perfectly straight line. The common screw is shown at diagram No. 11, and the Vansittart screw is shown on diagram No. 12, while table No. 9 gives particulars of both.

Trial of H. M. S. Fancy with the Lowe-Vansittart propeller, made on the 24th June, 1868, against the common screw manufactured by Messrs. Penn.

Description of propeller	Common screw in gun-metal	Lowe-Vansittart in iron
Where tried, Portsmouth		
Draught of water forward	6 ft. 8 in.	7 ft. 1 in.
" " aft	6 ft. 8 in.	7 ft. 1 in.
Area of mid-section, immersed	134 square feet.	40 lb.
Steam pressure in boilers	35-39	37-69
Mean pressure in cylinders	180-19	153-3
Mean revolutions per minute	194	176
Indicated horse-power	7-9	7-9
Speed on measured mile, mean of 6 runs	7-9	7-9
Duty performed, or speed $3 \times$ mid-section, I.H.P.	374.5	377.8
Diameter of propeller	6 ft.	6 ft.
Pitch of ditto	6 ft.	7 ft. 1 in.
Remarks as to vibration	Considerable	Very slight.

Diagram 13 illustrates a propeller designed by Captain Rothwell, of the Cunard steamship Parthia. His object was to reduce the vacuum or back drag, and to give greater strength and efficiency to the blades without adding to the weight. To attain this end, the propeller was arranged as shown, a small blade being placed partly behind the larger one, and set a little coarser, both blades being set so that the leading edge of the rear blade and the rear edge of the large or leading blade are parallel with the line of shaft, both blades being curved, the large one convexed aft, the small one convexed forwards, both peripheries being connected. This form of blade can not be broken, it is claimed, by a sea striking it. The rear blade receives a clean thread of water and throws it off with the same velocity as the leading blade, thus destroying the back drag or vacuum of the large blade and reducing it to what would be found behind the small or rear blade. Also partially preventing the water from fouling or honeycombing the fore side of the blade; as the bladelet could be bolted on to the large blade, thus saving a new propeller, as some ships wear a propeller very quickly from that cause. Captain Rothwell says: "I have great faith in it reducing the vibration, on account of its peculiar construction, rotating in a volume of irregular density, this being the chief cause of vibration in ships propelled by the screw; a ship plunging into a heavy sea, as her stem falls the descending blade has an immense resistance opposed to it, while the opposite or ascending blade had its burden greatly lightened, causing the pressure of propulsion to be so unequal that if there is the least chance of looseness in the stern gland, or the shafting or bearing blocks not very firm, the result is great vibration, independent of what may be caused by the engine racing when the screw rises out of the water. In respect of the action of the propeller on the helm, with a right-handed screw, steaming full speed, most ships carry a little starboard helm. If one of such ships were to have her engines suddenly stopped and reversed full speed astern, the helm being placed amidships, then her stern will incline to starboard. I have always noticed that ships with a long fore-gripe turn very badly either way, and when moving either ahead or astern."

The next propeller for notice is that of Dr. Collis Browne, shown in diagram No. 14. It appears to be a right and left-handed screw, but it is not so, as the four blades really represent the action of but two, as it will be seen that one of either pair of blades is one portion of the same spiral as that of its companion. The performances of this propeller on board the Galatea, Trinity-house launch, were such that the same work was done by it by 60 lb. of coal per hour as was done by a Griffiths screw with a consumption of 80 lb. per hour.

Diagram No. 15 shows an arrangement for employing a supplemental screw to assist in steering a ship. Three mitre wheels transmit the motion of the main shaft to the supplemental screw mounted within the rudder. From the mode of arrangement it will be seen that the rudder has perfectly independent action, while at the same time the action of its contained screw is to force aside the ship's stern either to port or starboard. It is the invention of Mons. Victor Lutschaign, Professor of Naval Architecture to the Imperial Academy at Trieste. He read a short paper on the subject before the Institution of Naval Architects in March of last year. In it he stated that the idea of swivelling the propeller of a ship in order to make it serve also as a means of steering, dates back to the year 1832, but that the practical difficulties of working the scheme with large ships were such as rendered that idea utterly impracticable. He therefore devised his scheme by which the main propeller is left to fulfil its legitimate functions, another independent screw being added for steering purposes. He further stated that his scheme was applicable to balanced rudders, but that they would no longer be requisite where his plan was adopted with his supplemental screw, it being preferable to balanced rudders; that critics of his system have suggested universal joints instead of toothed gear, but that his reply has been to them, first, that as it is expedient that the supplemental screw should revolve in a direction opposite to that of the main screw, toothed gear becomes a necessity; and, secondly, that by the use of a universal joint the rudder could not be unshipped. The advantages claimed are great increase of steering power; the possibility of turning the vessel from her position of rest, with the first revolutions of the engines; from the use of two screws revolving in opposite directions, the evil of a ship moving with a port or starboard helm is obviated; and that the rudder can be unshipped or shipped while the vessel is afloat.

The author now invites the attention of members to diagram No. 15A, which illustrates one of the most recent arrangements for feathering the blades of a screw. It is the invention of Mr. R. R. Bevis, of Messrs. Laird Bros., Birkenhead. The leading feature in the contrivance is that a portion of the shaft is hollow, and within is a rod riveted in the screw-boss with cranks upon the blade-shanks, and united at the other with a screw-collar on the shaft, and by this arrangement Mr. Bevis is enabled to feather the screw from the engine-room—a matter of advantage in war-ships, by placing all below the water-line. The thing has been successfully

tried in Mr. Brassey's yacht, the Kathleen, and after twelve months' service was found in good order.

Turning now from the forms and performances of screws in actual practice, the author invites the attention of the members of the Society to a different and more theoretical or experimental branch of screw-propeller action, and he gives the following abstract of certain experiments instituted by Professor Osborne Reynolds, to investigate the causes of the phenomena of racing observable with the screw when at work. In a paper read by Professor Reynolds on this topic before the Institution of Naval Architects, in April, 1873, he remarks that the tendency which the screws of steamships have under some circumstances to lose their hold of the water, appears to have its causes enveloped in mystery, for although the circumstances under which this racing occurs are such as appear, *prima facie*, to afford an explanation of it as being due, for instance, to the pitching of the vessel, exposing the screw at certain intervals, yet a closer examination indicates that something more than this is requisite, the mere casual stripping of the screw being, in his opinion, not sufficient to account for the screw losing its hold of the water; citing, as a proof of this, the tendency that a screw displays to race in the smoothest water, if working against a great resistance, as when towing another vessel, or even when starting its own. He states that his attention was attracted to this subject by the connection between the breakage or disturbance of the water-surface, and the consequent admission of the air to the blades. He remarked that the screw never raced without getting air, and the admission of air was always followed by racing. With the view of satisfying himself on this subject, he tried numerous experiments, one of which was made with a model fitted first with a screw of a small diameter, and which had about 1 inch of water covering, and the other was with a larger one that had but $\frac{1}{2}$ inch of covering. When the boat was held still, the small screw did not race, whereas the large one did. In the opinion of the author, the tendency evinced by the thinly-covered screw to race is due, not alone to the suction of the air, but also to the fact that any screw will race if it has not sufficient water to react upon, and as the resistance of the water must depend upon its solidity, so to speak, it follows that when a screw is near the surface of the water the column acting against the thrust of the screw becomes broken, and the screw, losing resistance, races.

In the end of March, 1874, Professor Reynolds read a paper before the Institution of Naval Architects on the effects of immersion on screw-propellers, and he commented upon the results of two series of experiments—see Table No. 10—made by him with a model screw, 2 inches in diameter, and caused to rotate by a spring.

Professor Reynolds' First Series of Experiments where same strength of spring was used.

Number of Experiment.	Depth of Immersion.	Time taken to Run Down.	Remarks.
		Seconds.	
1	1	19	Did not race.
2	2	19	"
3	3	20	"
4	2	20	"
5	1	20	"
6	$\frac{3}{4}$	20	"
7	$\frac{1}{2}$	20	Raced a little at starting.
8	$\frac{1}{4}$	12	"
9	$\frac{1}{8}$	12	"
10	$\frac{1}{16}$	12	"
11	0	12	"
12	0	12	"
13	— $\frac{1}{8}$	10	"
14	— $\frac{1}{16}$	7	"

Professor Reynolds' Experiments.—Second Set, where a stronger spring than in last series was used.

Number of Experiment.	Depth of Immersion.	Time taken to Run Down.	Remarks.
		Seconds.	
1	3	10	Did not race.
2	1	10	"
3	$\frac{3}{4}$	11	Raced at starting.
4	$\frac{1}{2}$	11	"
5	$\frac{1}{4}$	9	Raced intermittently.
6	$\frac{1}{8}$	9	"
7	$\frac{1}{16}$	6	"
8	$\frac{1}{32}$	4	"
9	0	4	"

From the results of these experiments, Professor Reynolds deduces that, so long as the screw is not frothing but working in solid water, the resistance is independent of the depth of immersion, and he calls attention to the point that when a boat is stationary, there is a much greater chance of the screw drawing down air than when it is under way, illustrating his remarks by referring to observations made by him during a voyage on board the Palmyra, whose screw, although eight clear feet under water, frothed the water before there was "way" got on the ship, but did not do so once the vessel was in motion.

In reference to the question of the immersion of screws raised here, the author would call the attention of members to diagram No. 16, which shows Messrs. Harland and Wolff's arrangement fitted to the Britannic, intended to furnish a deep immersion by lowering the screw to an angle with the ship's keel when in deep water, the connection with the engine-shaft being made with a somewhat peculiar universal joint. When in shallow water, the screw is raised so that the tip of the lower blade is above the keel, but at sea the screw is dropped. The results obtained with this arrangement are said to be excellent.

The author now proceeds to the consideration of the second portion of his subject—namely, the shafts and fittings of screw-propellers; about these he ventures to think there is still a good deal to be learned. The best form, as well as the best mode, of fitting a shaft, which has to transmit on occasion the strain of engines exerting, it may be, 8000 horsepower, deserves attentive consideration, more especially when it is remembered that the safety of much valuable property depends frequently on the trustworthiness of a screw-shaft. The whole arrangement of these shafts involves some of the nicest questions of mechanical science. It is at all times a nice matter to centre truly a considerable length of shafting, even to a series of rigid supports, but the difficulty is greatly increased when, as on board a ship, the supports are not rigid, but yield with each strain and "working" of the vessel's hull. The author will refer to one out of numerous examples of the failure—first of a screw, and then of a shaft—illustrating the importance of this question. This was the case of the Atrato, which sailed from Plymouth for Australia, with some hundreds of emigrants on board, on the 17th Septem-

ber, 1872. On the 19th she returned with her screw broken. The damage was made good and she put to sea again, only to return again, however, about the 26th October, with her shaft broken. Diagram No. 17 shows the general nature of the fracture. This second mishap gave rise to a lengthy correspondence between Messrs. James Watt & Co., who made her machinery, and the Board of Trade. By order of the House of Commons, this correspondence was printed. Subsequently the Board of Trade sent a circular to all its marine machinery surveyors—thirty-two in number—requesting them to forward, in a tabulated form, the rules they adopted for calculating the diameters of screw-shafts. This table, which can be seen in the printed report of the Board of Trade, gives respectively the names of ships, the makers of engines, diameters of the cylinders, length of stroke, steam-pressure, diameter of shafting abaft of the crank, and diameter of same as obtained by the rule the surveyor uses. Two columns of the table are bracketed together under the common head of differences between diameters of existing shafting in the vessels named and the sizes obtained by the surveyor's formula—the one column containing the amount less than existing shafting, and the other giving the amount greater than existing shafting in the respective vessels named. A list of thirty-eight ships was given. Some of the surveyors used respectively rules of their own, and of the remainder some used Rankine's, some Molesworth's, and some Anderson's rules. The table, No. 11, gives a few of the more striking examples selected from these figures.

Atrato's Shaft.	
Actual diameter of broken shaft.....	12 inches.
Proper diameter as computed by surveyors:—	
By Rankine's rule.....	13.7 "
Anderson's rule.....	13.4 "
Molesworth's rule.....	13.9 "
Caird and Company's rule.....	13.4 "
Mr. J. Rose, Hull Surveyor.....	14.0 "
Mr. W. Wheatley, Cork.....	14.4 "
Spencer's, used by Mr. Bipet, Liverpool Surveyor.....	13.2 "
Mr. G. Carlisle, Leith Surveyor.....	13.4 "
Mr. R. Taplin, Liverpool Surveyor.....	13.2 "
Mr. Snowden, London Surveyor.....	13.9 "

Particulars of the engines (compound):—Diameter of high-pressure cylinder, 57 in.; diameter of low-pressure cylinder, 90 in.; stroke 4 ft.; pressure of steam in boilers, 60 lb.; cut-off at about two-thirds stroke in small cylinder.

The sizes of shaft suitable for the Atrato's engines, deduced by the various surveyors, were from $\frac{1}{2}$ in. to about 3 in. greater in diameter than the shaft which broke, and which was 12 in. in diameter; hardly any two surveyors, however, found the same dimension. In the author's opinion, the probable causes of the fracture of shafts and propellers is due, in a great measure, to the almost total absence of any adequate torsional elasticity between the propeller and the engines. Hence, when the screw makes some revolutions out of the water, or it draws down air, then the engines race, and afterwards the screw may become suddenly and deeply submerged, throwing an abrupt strain on the cranks, causing the ship to tremble fore and aft, and some weak point in the shaft probably gives way, leaving the ship a helpless log upon the waves. In the author's opinion, two remedies present themselves for this evil; the one offering the prospect of greatly reducing the chances of fractures taking place, and the other of repairing such fractures when they do come. The former method is to provide some elastic or flexible arrangement between the screw and the engines, so that each could have some movement independently of the other. Common sense dictates this, for the engine is subjected to one set of strains and the screw to another entirely different set, and these two are seldom or never in unison. Hence, there are times when something between the two must give way, whereas, by allowing a little independent motion to the screw, the shocks and strains now so destructive would be avoided.

The introduction of torsional elasticity alone is not enough; some longitudinal elasticity as well is wanted. The diagrams Nos. 18, 19, 20, and 21 illustrate arrangements invented by the author some years ago, to provide torsional and longitudinal elasticity. The torsional is provided for by the cage of flexible blades between the two discs—see Fig. 18. The longitudinal elasticity is provided by arranging the thrust block in a pair of guides T T, in which it can slide and bring the buffers P P to bear against the springs S; while to provide against any violent recoil, the two air cylinders shown at R are bolted at the stern or aft ends of the guides, and in these are pistons packed with cup leathers in such a way that no obstruction is interposed to the forward or thrust motion of the shaft. If a sudden stoppage or reversal of the engines takes place, then no violent recoil can occur, because the pistons encounter a cushion of air, and they can only recede as the air escapes through the two air cocks shown on the aft ends of the cylinders, and these are so designed as to have a leakage space, so that the engineer can never perfectly close them, though he can regulate the degree of rapidity with which the air can escape. Diagram No. 19 shows a simpler plan of providing torsional elasticity than the foregoing, and is intended for steam launches and other small craft. It consists in forming an intermediate portion of the shaft of a single broad steel blade, which affords considerable torsional elasticity. The longitudinal elasticity is provided for by making a square box-end on the one part of the shaft, and a corresponding square end to fit on the other part of the shaft; this latter bears against a buffer spring within the box; a sectional view is shown on diagram No. 19. Diagram No. 22 illustrates a coupling invented by Mr. F. H. Varley and Mr. E. Furness to secure the same end. It consists of a box, into which is closely but freely fitted a species of piston or block, the one end of which is a simple plane, while the other, or outer end, is shaped as a spiral. The box A in which it works is secured to one length of shafting, while to the corresponding length is fixed the boss B, which has a projection, the extremity of which has a spiral matching that on C. If undue strain comes on the shaft the spiral faces slip, and the block C is forced up against a reservoir of oil, water, or air; or else an elastic india-rubber cushion is interposed. The device is intended either for screw or for factory shafts.

That the principle of such arrangements as have just been described is sound has been demonstrated under severe test, and with great success. Mr. Jeremiah Head, of Middlesbrough, has invented, and successfully applied, an arrangement for introducing torsional elasticity to prevent shock in reversing rolling mills. The arrangement consists in introducing cantilever springs, which are secured at their inner ends to a loose sleeve or box on the mill shaft, while their outer ends engage in projections on the wheels, so that when the clutch is shifted to reverse the movement, the motion is imparted, not through stiff and rigid studs, but through these, so to speak, flexible spokes.

As to the repair of shafts while at sea, the author is of opinion that if shafts were made of an oval section instead of a circular one, they could be more easily repaired. Some misapprehension seems to exist as to the author's meaning in advocating the use of oval shafts, many persons supposing

that he seeks to effect the rotation of an oval shaft in a bearing, which is an obvious absurdity. The author only proposes that shafts should be oval between the bearings, having proper journals at suitable points; oval shafts when broken could be clamped without the need of cutting key-ways or drilling holes in the shaft, as an oval can not rotate in the clamps, and because shafts break in the journal necks, he suggests that the entire shaft should be oval, and where a bearing is necessary, to put a steel sleeve—see diagram, Fig. 21—fitting the shaft, and having a circular outer face which may rotate in the bearing, when, if torsion break the shaft in the sleeve, the latter will transmit the strain. Several months ago a proposition for effecting the repair at sea of broken shafts was brought before the public by Mr. Cromwell Varley. The scheme consisted of a method of bolting and keying the pieces of a coupling box over the fracture, the weak point of the scheme being that key-ways, or flat places, must be cut on the shaft to prevent its rotating within the box without transmitting any torsional strain or power, which causes dangerous delay at sea in heavy weather. About December, 1872, the author proposed to place an ordinary coupling-box on every length of shaft when first made, to run loosely on the shaft; and when a fracture took place this box was to be slid over the fracture, keyed and bolted up, making at least a good patch.

Diagram No. 23 illustrates a coupling invented by Mr. John G. Winton, of Edinburgh, for repairing broken shafts. He remarked in a paper read before the Royal Scottish Society of Arts, that as screw shafts are usually fitted just as they come from the steam hammer, the repairing coupling can not be properly fitted. He allows an hour and a half as the extreme limit of time for repairing a fracture on board a ship in a heavy sea-way. He proposed two different couplings, the one resembling Varley's, the other being represented in the diagram. The former was to be made in halves, and strongly bolted together, so tightly as to bind the shaft sufficiently to take a part of the torsional strain, while cupped set screws, biting into the shaft, took the rest. The coupling in the diagram, and which does not come at all in contact with the shaft, depending entirely on the set screws, is the second scheme.

In reference to the strength of screw shafts, it may not be out of place to give the opinion of a gentleman of large experience. Colonel Clay, of the Birkenhead Forge Company, states that it is at present difficult to obtain first-class material for heavy shafting, a fact in a great measure due to modern methods of making and refining iron, the use of raw coal, combined with a hot blast, contributing to this. The *Jedd* was, some years ago, very unlucky, breaking two shafts in quick succession. A Krupp steel one was then tried, but it only lasted a few weeks, and was found by subsequent test to be too "steely" and brittle. A puddled steel one, supplied by Col. Clay, was next fitted, which lasted well.

An interesting example of what may be done by a skilful engineer under difficulties is supplied by the following case: The *Ethiopia*, a first-class Atlantic steamer, quite recently broke her shaft, on her voyage to New-York, when about 1500 miles from port, and the fracture was repaired at sea in the manner shown in the diagram No. 24. The shaft is 15 in. in diameter, and the fracture was a simple diagonal one. The broken parts were raised by jack-screws, the edges smoothed, and a 4 in. hole bored through the opposing portions, into which a bolt was tightly fitted. Four steel drivers 4 in. long, $1\frac{1}{2}$ in. broad, and $\frac{1}{2}$ in. thick, were sunk into the shaft, flush with its surface, just across the line of fracture. The whole was then tightly clamped by hoops bolted on the shaft. The vessel prosecuted her voyage safely to New-York, and is to come home as she is for repairs, the shaft being considered reliable for the voyage. The repairs occupied eight and a half days, working night and day. Of course this could not have been done in heavy weather.

The author's scheme for repairing broken shafts is shown on diagram No. 21, and diagram No. 21A shows an oval shaft with a separate steel journal neck; this latter receives no torsion till the shaft fail within it, when it at once transmits the power past the fracture. Diagrams Nos. 12 and 13 are tables of fractured and defective shafts. The one table No. 12 gives particulars of shafts actually broken at sea, and the ages, mileage and materials are all given, as well as the place and description of fracture. Table No. 13 gives similar particulars of shafts found on examination to be faulty, and therefore condemned.

The data were collected by Mr. Cameron, of the Wilson line of steamers, during his professional career.

In conclusion, the author desires to summarize the foregoing paper by observing that the question of screw propulsion appears to him to depend, so far as the screw itself is concerned, not so much upon any particular form or number of blades fitted to any given propeller, as to the due adaptation of them to the lines of the particular vessels being fitted; that it is a mistake, and causes much needless complication of a subject already difficult, to confound or mix up the economical performance of engines with that of screws; that the performance of a screw can not be measured truly without taking account of the form of hull it acts upon; that the mere measurement of the excellence of hull, engines, and screw can not be alone determined on the basis of the quantity of coal burnt per mile, but that the proportion of dead weight to paying load and also the maintenance cost must be taken account of. Propellers with more than two blades appear to cause the least vibration, and to some extent give a ship a greater margin of safety than the two-bladed screw, because each additional blade is an increased reserve. The author also—while admitting that great progress has heretofore been made in the development of the system of propelling vessels by means of the screw—is of opinion that there are still points of obscurity that need to be cleared up.

HUMAN HANDS.

A CORRESPONDENT who sends to *Nature* the results of his study of palmistry says: "I have made a collection of more than fifty outlines of the fingers of European hands (right and left). At present I find the tendency in the female hand is to a proportionately longer third than index finger in both hands, than in the male. In all the hands I have examined the third finger of the left hand (when longer than the index) is also proportionately longer than the same finger of the right. In this series I have found only one case of an index longer than the third, and only one in which they were equal (both males). These are all carefully drawn in a pocketbook, care being taken that the hand is perfectly free from any muscular strain, which alters the result appreciably; and the race, sex, and general physical characteristics are noted on the sheet. The list at present includes some classical scholars, a distinguished artist, and numbers of persons of more than average culture; yet there appears to be no correspondence between the mind and the length of the index finger."