have fairly long high speed drive shafts and the mounting of turbines and gearbox on a flexible airframe introduces problems associated with shaft mal-alignment The original toothed couplings on these shafts, have been replaced by specially designed ball couplings These are capable of standing a greater degree of mal-alignment and are based on a similar coupling, operating successfully in the Gazelle installation

The high speed shaft on each turbine connects to the clutch which is also the fluid drive, and then through the primary reduction gear, which incorporates the torquemeter, into the lower part of the main gearbox The fluid drive introduces a heat dissipation problem, and reacts on consumption, but the advantage of a non-mechanical link in the transmission, will, we are confident, outweigh the disadvantages

The lower part of the main gearbox, of Westland design, is connected to the upper part which is Sikorsky designed and manufactured This upper gearbox contains the final double epicyclic gear reduction and the total gear reduction is 12,500 turbine R P M down to 197 rotor R P M

As this paper goes to print development testing of our first twin turbine installation in the Westminster is about to start, and shortly we shall be in a position to assess the extent of the development programme

To sum up, based on experience to date with one trial installation of a single turbine, I would say without hesitation that development time and effort can be saved, compared with a piston engine installation of comparable power

The piston engine has been the mainstay of helicopter development up to this date, has given good service, and where first cost is an important consideration, will compete with the turbine for some years to come, particularly in the smaller sizes where engine development continues

The turbine is the more sensitive to altitude combined with high ambient temperature Where such conditions have to be met, as in a world wide Operational Requirement, an oversize turbine must be installed, probably run in a gated condition at sea level I S A This tends to increase first cost and the gating reacts unfavourably on consumption

However, taken all round I am sure that the many advantages of turbine power outweigh the few disadvantages, and that better helicopters will result from its use It will no doubt have been noticed that throughout the paper an open mind has been maintained on the best arrangement of helicopter turbine In my view the only characteristic which distinguishes the helicopter turbine is the ability to operate continuously at angles far outside fixed wing practice Given a basically sound turbine with this ability, then I think a satisfactory power plant for a helicopter can be provided with either fixed or free turbine, with front or rear drives

In conclusion I must thank my staff for compiling the material for this paper, my Company for providing the facilities, and the Sikorsky Division of United Aircraft Corporation for providing some of the photographs used for illustration

Discussion

The **Chairman** called upon Mr Boddington, of the Ministry of Supply, to open the discussion

Mr L Boddington (*Ministry of Supply*) recalled that in his introduction the Author had said that he would confine his talk to a subject matter which was fully within his experience, and in the written paper he had confined this to the last year Having been associated with him for many years on the problem of the turbine engine helicopter combination, Mr Boddington could give the assurance that whilst the Author's experience was beginning to show results during the last year, he had spent quite a number of years in studying the problem He was, indeed, of not inconsiderable experience covering the complete span of turbine engine applications to helicopters

The Author was to be congratulated on completing the first practical stage in achieving the first engine run on the Westminster on 1st June It was difficult to say whether, in actual fact, he had shortened the time-scale, because it was a private venture, or whether we missed out on the Wessex because it was one of those projects which enjoyed what is now called "financial support" In any case, it was hoped that the Wessex would soon catch up

The Author had raised a number of controversial points and had spotlighted them admirably in his lecture In the ensuing discussion, no doubt these points would be taken up and argued to the full Indeed, without adequate discussion of some of these points, the lecture would not be complete

The first of what Mr Boddington regarded as the important points was the choice of the free or fixed turbine, which was a favourite item for discussion Opinion might be weighted very much in favour of the free turbine, but perhaps there was a certain amount of influence from the question of avilability Having taken part in many discussions with the Author and others concerned with the problem, both in this country and in America, Mr Boddington derived a little comfort from the fact that he could score up many more free turbine installations than fixed turbine installations He was, perhaps, one of the various authorities who believed in the free turbine It was, perhaps, the right overall answer from the military helicopter point of view It was certainly proving to be the answer in the Wessex and in its particular application to the anti-submarine project

The Author had stated the pros and cons for the free turbine very fairly, but pros and cons were, in fact, a prerequisite to a decision, they were not a prerequisite to indecision Nothing had been said to indicate that a precise decision on the use of the free turbine would be wrong Admittedly, it was necessary, perhaps, to examine the several variations Indeed, two or three years ago, when the commitment for the present programme was undertaken, that was the position

As far as one could see, the problem with the military aircraft — it was not quite so straightforward with the civil application — was not a question merely of an engine, its fuel consumption and its installed weight and anyone of these three separate elements governing the decision The factor on which comparison must be made is the engine plus fuel weight in any particular application

Here again, in the military application of the Wessex, it had been possible to show that this was an extremely good combination In studies of re-engining existing helicopters, it had been possible to show that it would be worth-while and that the military performance of aircraft which were now in service could be improved considerably if they were engined with the gas turbines now being offered

On the civil side, of course, other factors arose One did not mean to suggest that the Services were not concerned with the cost of fuel or, indeed, with the cost of the first installation, but did the low cost of fuel and its safety truly offset the fuel consumption?

Considerable foresight had been shown in the layout of the Westminster, which was typical of the shape of the helicopter to come, concerning the relationship of rotor, transmission and engine This integration had been conceived by the Author well ahead of any of the Sikorsky arrangements It represented a very versatile arrangement whereby the gondola cab, or whatever else one chose to call it, could be made at comparatively lower cost to suit the particular requirement, retaining the basic rotor-transmission-engine combination

Mr Boddington did not ask any questions himself but hoped to hear a very virile discussion on the free turbine versus the fixed turbine It was an extremely fascinating subject for discussion, and there were many in the audience who held views firmly for one or the other

The **Author** thanked Mr Boddington for his opening remarks and would comment on two points which he had made

The first was that he had indicated that there had been a race between the two types under development, which the Westminster had won by a short head up to the engine running stage Although the Author would not deny that there had been a slight spirit of competition, it could not be considered a race as there was no comparison between the two programmes The Westminster was an Experimental job with the minimum of tooling and a large amount of hand work, whereas the Wessex was securely based on a 100% tooling programme with production series already building up It was therefore purely coincidental that they were both coming up to the flight stage at the same time

Secondly Mr Boddington had said that the arguments concerning the relative merits of fixed and free turbines could be an indication of indecision, possibly influenced by availability The Author admitted that the paper could be read in that light but until actual experience had been obtained with the two types of installation it was important to avoid dogmatic statements

One intention of his paper was to show that a turbine did not necessarily have to comply with a particular formula to make it suitable for a helicopter power plant, and provided it had angular freedom of operation, probably any good turbine could be converted into a successful helicopter engine

Mr B S Shenstone (*B E A*) (*Member*) said that the two worst things about helicopters appeared to him to be vibration and noise He was firmly of the belief that the turbine got rid of the vibration He had flown for about an hour and a half in a non-turbine helicopter and that was enough — in fact, more than enough — but he looked forward to flying considerably longer than one and a half hours in a turbine helicopter

Noise was one of the main problems than at airline had to deal with If it was not being accused of making too much noise, it was accusing somebody else of doing so It was, therefore, important to think about it and do something about it

Everybody talked about the noise that turbine engines made, but the Author had stated that they did not make as much noise as piston engines Curiously enough, that was perfectly true Mr Shenstone had seen and heard four types of turbine helicopter in flight and all of them were less noisy than the piston-engined machines The Author had not gone into this and explained the reason for it The Dart engine in the Viscount was very noisy indeed A vast amount of noise came out of the front and almost as much, of a different kind, came out at the other end

Here, however, a different problem arose Although the Dart was a nice piece of machinery, it was not very modern and was not highly efficient In talking about new shaft turbines, which were much more efficient, it could be assumed that instead of the exhaust rushing out madly at a great velocity, most of the power would be absorbed mechanically and the exhaust would simply dribble out and be relatively noiseless

The problem concerning the front end had been practically answered in the paper Something must be put around it so that the noise did not come out directly This was fairly well proved when comparing the Dart engine installation and the Proteus installation In the Proteus, the air wandered all over the place before it got near a compressor and the noise had no chance to get out This was something to be remembered in any of the turbine installations in helicopters, to make sure that the air wandered about and went round corners before it got into the compressor This had been done for other reasons in the Wessex

The Westminster, however, judging from the layout which had been shown, would be extremely noisy on the intake end This would be a great pity and something might have to be done on the front end of the engines Compressor scream was an annoying sort of noise Instead of having the intakes facing forward, it might be necessary to have them bent upwards

One did not have to worry about the "q" in these intakes, because one was designing for zero as well as relatively slow forward speed The fact that upward-turning intakes on a machine like this would make it rather like a two-funnelled steamship did not matter, and it gave an opportunity to put the "W" on both funnels!

Mr Hollis Williams thanked Mr Shenstone for not asking inconvenient questions Experience with the Westminster intake from the noise point of view was somewhat limited, but he had noticed on the tie down base that compressor noise was noticeable over a limited arc in front of the helicopter, and it might be necessary to introduce some form of sound deflection or baffling

Dr G S Hislop (*Fairey Aviation Company*) (*Member*) said that he had enjoyed the Author's straightforward account of the Westland work When looking around the audience, however, it seemed that he was possibly in the lions' den as the protagonists of the mechanical drive were really out of force He proposed, therefore, to ask one or two specific questions relating to the topics in the paper, in the hope that the Author could shed light on them

Dr Hislop was very interested in the Sikorsky ventures into turbine drive, in their second attempt they elected to adopt twin free turbine scheme but thereafter they had installed a single free turbine Were there any particular problems associated with the twin free turbine installation which dictated that approach? Was there a governing problem, or a load-sharing problem?

A paper by Mr Hafner some months ago had pointed out some of the problems which might arise in the event of engine failure with the sudden throwing of power from one engine to the other, or, in the event of incorrect matching of the two engines, the consequences of a sudden demand or a sudden reduction of power might well give rise to a serious power sharing problem If, in the view of the Author, that problem existed in the Sikorsky experience, was it likely to be a serious one or one which could readily be overcome in multi-engine installations with free turbines?

On the question of the governing of fixed turbines, the Author had said that they were fairly all right provided there was plenty of reserve power, and in principle one would agree with this What did the Author regard as the reserve power margin which should be considered? Taking the 100% r p m /100% torque point as a basis, should one have a reserve of the order of, say, 25% torque at the same r p m , or should it be 10% or 50% ? It was issues like these which governed the size of the engine and, hence, this markedly effected the economy of the aircraft

In thinking of the fixed and free turbine problem, one had always imagined that with the free turbine there was no problem in starting the engine but keeping the rotor stationary It was therefore of interest to hear that the problem of holding the rotor with an idling compressor had proved virtually insuperable on the installations so far Could the engine people help in this respect? Had they any means of reducing the mass flow through the compressor in this condition so that the free turbine torque was reduced, thus enabling an acceptable brake to hold the rotor? One could well visualise that there might be a serious operational objection to the state of affairs reported by the author

The Author had shown the effect of putting in a flight idling stop to deal with the quick stop manoeuvre The flight idling stop was well known to all who were involved in turbine powered flight One could put in a flight idling stop wherever one liked, but it could have its embarrassments because it meant that the minimum power of the rotor in flight might be raised too high From the curves shown by the Author, this minimum power had been raised by a factor of 2 Was this an embarrassment?

The Author had spoken of the measurement of the Mil VI rotor as being about 84 ft It was, however, thought to be considerably more than 84 ft One report, from an Intelligence source, put it at about 105 ft , whilst another report, a translation from a Polish journal, put it at about 135 ft It would be interesting to know whether anybody else had information concerning it

The **Author** (in reply to Dr Hislop) said that he did not propose to deal with the question concerning the governing of twin free turbines as he thought that Dr Moult would be more competent to deal with this as de Havilland were already receiving full information on the T 58 turbine, in view of its licence arrangement to produce this turbine in England, where it will be known as The Gnome

All he would say was that there had been some initial difficulty with load sharing and he had no doubt that Sikorsky would find the installation of the single T 58 in the S 62 a much simpler problem

With reference to the question concerning the size of turbine to give an adequate amount of reserve power, the Author said that there was no simple answer to this — it depended upon conditions of altitude and temperature in which the helicopter was required to operate

Concerning the question about a rotor brake, the Author said that on the run up a stationary rotor could be held with the compressor set running at ground idling r p m , but with the rotor system rotating, as after landing, the energy of the rotor system plus the torque from the free turbine, at ground idling speeds it was extremely difficult to stop, and the type of rotor brake to do this in a reasonably short time would be prohibitive in size and weight It was therefore decided not to attempt to meet this condition, and the gas generator would be shut down before attempting to stop the rotor The introduction of a flight idling stop to give rapid acceleration had not been found to be any embarrassment in the case of a helicopter, as it sometimes had on fixed wing aircraft

The Author was pleased to have Dr Hislop's comments on the size of the Russian Mil 6 helicopter, which might well be much larger than he had estimated from the published photographs

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The CHAIRMAN, referring to the subject of multi-engines, said that it was hoped to hold a lecture on this subject next winter, when these would be discussed, not only the coupling of multi-engines to a single rotor, but also the coupling of multi-rotors to a single engine and the coupling of multi-rotors to multi-engines This was on the Association's programme for next year

Dr E S Moult (*De Havilland Engine Co*) said that he would like, first of all, to deal with the point raised concerning the use of coupled gas turbine engines He was, perhaps, not as well-informed on this point as he ought to be, but he had had the opportunity of talking to both the engine and helicopter construc ors As was fairly apparent from the illustration shown by the Author, the converted S 58 was essentially a 'flying test bed' evolved to obtain early experience of coupled gas turbines in a helicopter The engines were in the cabin and not on the roof — as seemed now to be the preferred location The gear box had been improvised to couple existing engines to an existing rotor drive and there had been a certain amount of mechanical trouble in consequence

In addition, there had been problems of control and in the equal division of torque between the two engines The speeds of the output turbines were common, in any case, because they were coupled at the gear box their torques would depend on the speed of the gas generators and the quantity of fuel supplied to each engine There might be difficulties, but there was nothing fundamental or not capable of solution Dr Moult said that his Company had not been concerned so far with multi-engined drive to a single rotor undoubtedly that would come

He congratulated the Author on an excellent dissertation on the relative merits of the fixed-shaft engine and the free turbine engine there was little on which an engine man might comment in a critical sense There was, however, another possible arrangement not mentioned by the Author, which they themselves had explored some time ago This configuration employed a compound or "two-spool" compressor, each element driven by its own turbine, one of these turbines was "oversize" and the surplus power constituted the output of the engine The characteristics of such a combination would be found to be somewhere between those of the free turbine and the fixed-shaft engine Dr Moult said his own preference was for the free-turbine design on the grounds so well explained in the Paper

In comparing different types of engine one usually assumed identical component efficiencies and it followed that outputs and consumptions were also identical This applied rigorously at the design point differences in behaviour between types would occur during transients and at part-duty conditions The one advantage of the fixed-shaft engine when running at a high constant speed was that more power could be obtained simply by pouring in more fuel There was no delay while waiting for the gas generator to accelerate At the same time one was limited by the surge characteristics of the engine and its ability to withstand the higher temperatures involved

Dr Moult said he would like to echo what the Author had said about intake protection Some had dismissed the problem too lightly, others had been unduly worried No doubt the true facts lay somewhere between these extremes A fair degree of protection was probably wise in any helicopter Certainly in military helicopters circumstances could arise where debris would be stirred up by the main rotor and could be inhaled through an exposed intake The value of ram in a forward-facing intake was quite small because of the modest speeds of helicopters One needed just a 'good' intake, where it faced was merely a matter of convenience and adequate protection If, incidentally, intake protection gave a measure of silence, so much the better

Replying to Dr Moult, **Mr Hollis Williams** said that he was delighted that such an eminent authority as Dr Moult was generally in agreement with his Paper

Dr A W Morley (*D Napier & Son Ltd*) said that the Author had given a paper for which a real need existed There had, in fact, been a hunger for this type of exposition The Association should be grateful in a big way to the Westland Company for following up the helicopter development in the United States and bringing the best of it to this country, and they had matched up the excellent Sikorsky development with the engines of the United Kingdom The Author had made a substantial point in saying that he would champion any helicopter gas turbine as long as it was of suitable size and able to run at any angle As far as one knew, only one engine in the world would do that at present, and it was a cause of satisfaction that it was a British engine

The Author had opened the subject of the fixed versus the free turbine The

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main points concerned the question of the transient operation of the engine One's view was that the free turbine was limited just as much as the fixed turbine on the maximum temperature, and that it was more in questions concerning the matching of the rotor r p m with the engine r p m that the free turbine — at least, from the manufacturer's point of view — was a rather better proposition

On the question of the acceleration of the fixed and the free turbines, Dr Moult had said that the acceleration of the fixed shaft engine running at constant speed was "infinite" That was true if one could forget the perturbations in the turbine inlet temperature But with the free turbine engine at constant output speed, most of the acceleration was also "infinite" It was the effect of the speeding up of the gas generator which tallied off the acceleration curve of the free turbine

In a relatively small engine, the delay due to the speeding up of the gas generator was very small indeed, and of the same time scale as that for the change in the turbine inlet temperature of the fixed turbine operating to the same temperature limitation Moreover, with the speeding up of the compressor of the free turbine engine, the extra airflow through the engine to some extent, cooled the turbine, and so for the same increase, in say, power, the free turbine had the advantage that it would finish up with a slightly bigger airflow and, therefore, a slightly lower temperature, which from the engine maker's viewpoint was an advantage

The question of the best type of engine intake loomed large in any discussion concerning engines for helicopters The engine firms had to face an awkward question, because they wanted their engines to fit both the helicopter and the fixed-wing machine So far, there was no doubt that the helicopter field is the more restricted of the two When the designers thought of the difficulties of making an intake that was ideal for the helicopter suitable also for a fixed-wing aircraft, they were inclined to commit themselves on the intake that was most suitable for a fixed-wing machine, and this was why there were rather more examples of the open-type intake This in turn led to the orthodox position of the engines above the fuselage of the aircraft, with power take-off just beneath the rotor head

Dr Morley wished to ask the Author a question about the use of a constant rotational speed for the helicopter rotor This seemed to be the way that helicopter practice was going, but it was not necessarily the best aerodynamically for the rotor Did the Author think that it would come in permanently as a feature of helicopter operation?

The Author, in reply, said he understood Dr Morley to have said that the free turbine had temperature limitations

Dr Morley "Every turbine has"

The Author Assuming, however, that a gas generator was running under its designed conditions, it was then possible to vary the power turbine speed and torque over a wide range without trouble from temperature limitations Was this not correct?

Dr Morley agreed that that was so in the Author's case He asked members to imagine that a correction (increase) in rotor r p m had to be made if the machine was at a high enough altitude, the compressor revs were already quite high The pilot would restore his rotor r p m by, in effect, overspeeding his compressor, which would correspond to going over the maximum turbine temperature

The Author Obviously, the compressor must be guarded With the free power turbine however, one could, if necessary, drop r p m by over-pitching, and still not run into temperature trouble Constant speeding was obviously very desirable To get optimum performance, there should be some change in rotor revs, but the practical answer was to constant speed probably with a variable datum

Mr T L Ciastula (*Saunders Roe Ltd*) (*Member*) said it appeared that the comparison of free and fixed turbines as far as the question had been discussed this evening, was mainly on engineering grounds What had to be taken into account was the advantages and disadvantages of each type of turbine in the actual operating conditions of which the most significant was operation at full load at, or near, the actual full power available from the turbines From the diagrams presented by the Author for the fixed turbine, it would seem that due to temperature limitation, a considerable margin of power above that which can be considered as full power would be necessary, which means, in broad terms, that the fixed shaft turbine should be somewhat larger

From the diagrams presented, it was difficult to visualise what would actually happen with the two types of turbine in these critical operating conditions, since the curves for power required at constant pitch versus rotational speed represented different conditions of A U W and power required

For the free turbine the essential characteristic is flexibility which would enable one to obtain efficient operation of the rotor system over the range of its rotational speed to cover take-off and hovering at full load in all temperature and altitude conditions at full power It was this freedom of choice of rotor speed at constant power which was the essential advantage of the free turbine The free turbine control system will be designed in such a manner that pre-selected rotor r p m can be achieved, the rotor speed being determined by existing conditions Unless an analysis of this type was made covering the performance advantages of the free turbine, the comparison will not be complete

One of the conditions which gave concern to the pilot, and at full load was critical, is so-called overpitching Overpitching was simply demanding more power than was available This resulted in the dropping of rotor speed and this, in itself, would not particularly worry anyone provided the helicopter itself did not drop or start losing height rapidly It is in these conditions that accidents are likely to occur Let us now compare the two power plants in these conditions when the full power is required from both types of turbine For the fixed shaft turbine, if the pilot called for more power than the temperature limitation permitted, he might be given a warning by some kind of device In order not to exceed the temperature limitation, it would be necessary for him to reduce the resisting rotor torque which would immediately drop the power of the fixed turbine and the whole process would diverge downwards due to the fundamental characteristic of the fixed shaft turbine, i e, rapid drop of power with rotational speed

Thus, in the conditions described, the only safe way out for the pilot, particularly if he did not notice the signal of the warning device in time, would be to call for more power from the turbine and then the alternative would seem to be to exce d the limiting temperatures and damage the turbine Therefore, in the condition of overpitching for the fixed shaft turbine, extreme attention from the pilot will be required and burning of the turbine can occur

On the free turbine, the situation was totally different, because in that case, if the higher resistant torque demand was made by increasing collective pitch, the rotor speed would drop, but because of torque characteristics of the free turbine the power itself would not drop Thus, the overpitching in itself would really have little significance except for imposing some additional torque loads on the transmission This point is of utmost importance

The torque limitations of the free power turbine is not really very serious because in conditions described, a drop of say 10 or even 15% in the rotor speed which would be something extremely large, will correspond to an increase of torque itself of the same order or perhaps 12% which, for normal transmission, should not cause any concern

It seems in fact, and the diagrams indicate this, that the real torque limitation on the power turbine is likely to occur during rapid accelerations when low free turbine speed is combined with very high compressor speed

Mr Ciastula did not understand why the control system of the free turbine should be more difficult than on the fixed turbine If anything, it could perhaps be a little easier

It was true that the free turbine has an additional degree of freedom and that a power turbine governor is required but, for instance, to maintain constant power at varying rotor speeds all that would have to be done is to keep the compressor speed constant Another important advantage of the free turbine was the fact that the rotor vibrations of aerodynamic origin which, whether one liked it or not, will exist particularly at fast forward speeds, will not be fed back directly through the transmission into the power plant itself It seemed obvious that it was a very good thing that there was no mechanical connection for this vibration to come back into the compressor part of the turbine

The problem of the brake, which the Author had raised, was an important and worrying one With the free turbine, however, it was thought that the solution would be to employ two brakes The difficulty on the Wessex, it was understood, was not to hold the free turbine when starting and idling but to stop it when the turbine was put into idling but the whole assembly, including the transmission and rotor system was running with the free-wheel engaged One possibility, for example, would be to introduce a separate brake which would be used only to decelerate the power turbine As soon as this was done, the free-wheel unit would immediately come into operation and the rotor itself would be separated from the power turbine Stopping of the rotor in this condition would then be identical to that with which we now have to

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cope and a standard sufficiently powerful brake would do the job The use of a separate brake to decelerate the power turbine would also be a useful means to check the operation of a free-wheel unit This solution has not been tried yet but we are thinking on these lines

Concerning the problem of piston engines, Mr Ciastula disagreed that because developments were still taking place in this country on engines up to 1,000 h p somebody should start designing a new helicopter with a piston engine It would be very difficult to persuade anyone to do so It was true that developments were taking place in this country, these being mainly connected with smaller power plants but they were really applicable only to designs which already existed and one would imagine that the new helicopter design with the piston engine was something which is very unlikely to happen

Finally, he wanted to ask one question which, admittedly, was a difficult one and it was as follows If the free power turbine version of the Eland were available, would the Author use it in preference to the existing unit on the Westminster? It seemed to him that the complexity of fluid clutch drive with 2% slip and attendant heat dissipation problem, could be eliminated by the free power turbine and that these devices are really a move towards free power turbine fundamental characteristics

The **Author** replied that in the early part of his remarks, Mr Ciastula had covered again, although from a slightly different angle, the question of fixed versus free turbine In presenting the paper, he had said that to get satisfaction with a fixed turbine, it was necessary to have reserve capacity and a governor In the case of the free turbine, a governor was not necessary, it could be operated manually The governor then became, except in particular circumstances, something of a luxury Whether it presented a difficulty, one did not know, but it was hoped that it did not This was one of the things to which the answer was being sought

On the question of vibration, he had already said that in the case of the Westminster he was happy to have some fluid slip between the high energy parts, which would obviate transmitting trouble and would give an off-speed signal for the governing

Mr Ciastula had suggested a double rotor brake, one on the power turbine and another on the rotor itself It might, in fact, come to this Various designs had been investigated but they had been rejected because of the weight

The Author agreed that it was difficult to sell a new helicopter with a piston engine, but probably one could still develop existing helicopters if a new improved piston engine became available

If a free turbine version of the Eland had been available, undoubtedly it would have been used However we are likely to run into a period when there will be fewer turbines from which to choose The engine manufacturers should be encouraged to feel that when they have a good shaft turbine of the right size, the designers will do their best to make a good job of it, whether it be fixed or free

The CHAIRMAN pointed out that the paper, which was entitled "The Turbine Helicopter", had been confined to the geared turbine helicopter, and he invited the Author to comment on the suggestion made by Mr Fitzwilliams a few years ago on the question of mounting turbine engines on the rotor blades

The geared turbine would be capable of long endurance and of carrying a moderate payload for short endurance At the other extreme, for a rate of fuel consumption many times greater, the ram jet would have a much higher percentage payload but it would be capable only of short endurance As a compromise between these two extremes there was the pressure jet arrangement, which had less payload than the ram jet but had a better endurance

Since the suggestion was made by Mr Fitzwilliams, studies had been made by Nicholls and others, who appeared to think that it was possible to obtain a blade-mounted turbine with substantially the same percentage payload as for the ram jet and if one were optimistic about fuel consumption, with about the same endurance as the geared turbine Thus the blade-mounted turbojet would appear to have the possibility for the first time of bridging the gap instead of passing through the 1-hour point In spite of the blade-mounted ram-jet having up to 20 times the fuel consumption of the geared piston engine or geared turbine, all the curves appeared to pass through the 1-hour point The gap might be bridged with the blade-mounted turbojet

Perhaps these assumptions were optimistic and there was a greater weight penalty in having the turbine on the blade In the opinion of the Author, would the end points of the curve come progressively nearer the origin until in practice the blade

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mounted turbojet would have a characteristic curve passing through the 1-hour point?

The **Author,** replying to Professor Bennett, said that he had opened up a completely new subject which could keep the audience there till midnight, but he thought it would be most fitting if he called on Mr Fitzwilliams to reply

Mr O L Fitzwilliams (*Westland Aircraft*) (*Founder Member*) said that in the circumstances he was obliged to speak in case there were any among the audience who thought he had changed his opinion, which he certainly had not He had hoped that the question would not be raised tonight The paper and discussion had been confined to turbines in shaft driven helicopters and it was impossible to deal fairly with the totally different question of tip turbines in the closing minutes of the meeting For example, in this wider context, he thought Mr Boddington's complaint of the Lecturer's "indecision" could not be justified In his opinion no final and "correct" choice was possible among the alternatives to which the paper and the discussion had been restricted

What were the engine people faced with? They were faced with developing an engine which would drive forwards or backwards and which went at any angle, which had a fixed or a free turbine or, possibly, a mixture of the two The helicopter designers asked for an engine which had the characteristics which they liked in a fixed turbine, but they also wanted to be able to vary the rotor speed What the engine people were doing was to spend their time designing modifications to basic engines in order to fit them into particular helicopter airframes, at odd angles and to meet odd requirements

What they should do was very simple They should get down to the design of a small, mild by-pass jet engine to work on the tips of the blades With such a thing, they could be absolutely certain that every improvement they made to that engine as an engine would result in improved helicopters, and they could concentrate on their proper business of engines and not on the business on which they had been expressing opinions this evening, which was how helicopter designers should design their parts

The Chairman's rough sketch was quite correct in its indication of the general superiority of the helicopter with tip turbo jet engines It was a pity that no studies had been done here to define these advantages more precisely so as to make it clear to the engine people what could be done with such engines if they existed On the technical problems involved in the design of such an engine he had done a good deal of work at one time, and four years ago had got out what he still considered satisfactory answers to the problem It was impossible to understand why they had not been taken up

In the meantime his Company had not been altogether inactive They had done some work, as had the Americans, but mainly they had relied on the really excellent co-operation of Mr Rainbow of the Armstrong Siddeley Company, who had conducted approximately five design studies in the period from September to January last The results had substantially confirmed the estimates and design studies put out by Mr Fitzwilliams in August, 1954 In particular the Armstrong Siddeley studies confirmed his earlier conclusions as to the main features of a solution to the bearing problem, this aspect of the problem having also been confirmed by Mr L F Hall of Napier as long ago as the Autumn of 1954

The meeting had been talking about problems concerned with the existing type of helicopter This type of helicopter still had a useful life in front of it, and it was surprising that the makers could build them as well as they did, but it was not the helicopter of the future and the sooner people realised this, the better

Mr Donald (*Fairey Aviation*), who recalled the scheme for hanging a Sapphire on the end of a rotor blade, said that at a rough estimate the acceleration on the engine would be about 1000 G How would a gas turbine with rotating parts work, and how would it be possible to stop it from twisting the blade gyroscopically?

Mr Fitzwilliams said that obviously the Author was not in a position to answer the question, which was, quite clearly, out of the line of the paper He could not himself answer it in a brief space of time, but the answers would be given in a report by Armstrong Siddeley within the next month or so

The CHAIRMAN, in closing the meeting, expressed the grateful thanks of the audience to the Author for his most informative lecture and congratulated him on having established for the helicopter a similar position in the naval field as had been achieved by some of his previous fixed-wing projects

The vote of thanks to the Author was accorded by acclamation, and the meeting then ended