THIRTEENTH EUROPEAN ROTORCRAFT FORUM

41

Paper No. 55

THE ROLE OF MANUFACTURER IN THE ACCIDENT INVESTIGATION

C. ARCARI

AGUSTA - ITALY

September 8-11, 1987

ARLES, FRANCE

ASSOCIATION AERONAUTIQUE ET ASTRONAUTIQUE DE FRANCE

1. Foreword

The paper aims to present the valuable contribution that the Manufacturer can give in an accident investigation in order to identify the probable cause and the corrective actions.
When the investigation requires full knowledge about the performance, in flight behavior, characteristic of parts, etc... of the aircraft, then the basic engineering and manufacturing data-bank available by the Manufacturer become of unique value.
The paper shows, through different cases, how the solution of the accident has been completely identified with the specific knowledge of the Manufacturer.
A number of helicopter accidents are presented with solutions identified such as critical torsional rotational drive shafts speed, in process manufacturing problems, inproper maintenance, sudden stoppage, etc...
The message of the paper is to support the involvement of the Manufacturer Representative whereas an investigation is in process and when the preliminary analisys calls for that; the man appointed has to be viewed with the great potential of several thousand people, behind him, with their knowlenge, history and culture and waiting only to be asked.
The involvement of the Manufacturer means more people thinking toward safety in design, in manufacturing, in maintenance and more people finding solutions for the future to prevent ripetitive errors.

2. The Manufacturer and its privileges

In Italy, Civil Aviation Authority is entrusted with the investigation of commercial aircraft accidents and in the event of fatal casualties the Judge can appoint an expert of his choice.
The investigation of military aircraft accidents is instead usually delegated to a specialized branch set up by the Armed Forces.
I wish to stress that either the Group of Technicians tasked with the implementation of the investigation of commercial aircraft accidents and the Group in charge with the expertise in respect of military aircraft, are both made up of quite capable and highly skilled technicians (of course in Italy and abroad as well) who have logged great experience in conducting this type of investigations and are also quite familiar with aircraft operations, reliability level of the entire machine and of each of its component items.
Civil Aviation with their experts from the Registro Aeronautico Italiano (R.A.I., the equivalent of F.A.A. in U.S.A) have logged up a considerable experience background in investigating past accidents, in processing failure reports sent in by the operators and in performing extensive maintenance operations, which in some instances assist in locating defects which are likely to prove as a possible source of accident.

As regards accidents with military aircraft, the appointed military commission also represents the operator of the aircraft and for the same reasons set out earlier, this commission has logged a considerable experience background.
Yet neither Civil Aviation nor the Military Commission can avail themselves of the following privileges:

1) A specific knowlenge of the design and history of the parts or aircraft prior to delivery by the manufacturer.

2) A Data Bank covering all the studies, analyses and substantiations carried out by the Manufacturer during prototype fabrication, production run and service.

Why did I term these factors "privileges"?
Because the fact of living the entire evolution of a product certainly constitutes a privilege as it is a privilege to know the reason for the selection of a process or material in lieu of other possible solutions.
It is further a privilege to know the results from a landing gear static test or from a wing longeron fatigue test.
And it certainly constitutes a privilege to rely on the potentiality offered by a fully organized Company with its facilities and technical staff ready to provide the required expertise.
It is for these reasons that I deem necessary the participation of experts from the Manufacturer in order to implement the investigations into aircraft accidents and I believe the few examples I am going to describe will prove significant in witnessing the importance of the presence of the Manufacturer's "eye".

CASE 1

The Cotter Pin

Description

A medium heavy helicopter flying a military mission on hostile terrain, experienced a sudden increase in gear box oil temperature and increase of oil pressure.
An emergency landing was performed succesfully with no damages and injiuries to the occupants; once on the ground the decelera tion rate of the rotor was abnormally high, up to a kind of sudden stoppage of main rotor followed by a rotation of the cabin.
A tragedy was missed by few seconds.

Investigation

Agusta has been promptly called on the scene by the Customer to perform on field investigation. Magnesium debris were found in the oil filter and the complete gear box remained seized; then it was removed from the helicopter and sent to Agusta plant for complete disassembly and examination.

Results

The whole gear box was taken down to pieces and each part carefully examinated by our experts.
What appened:

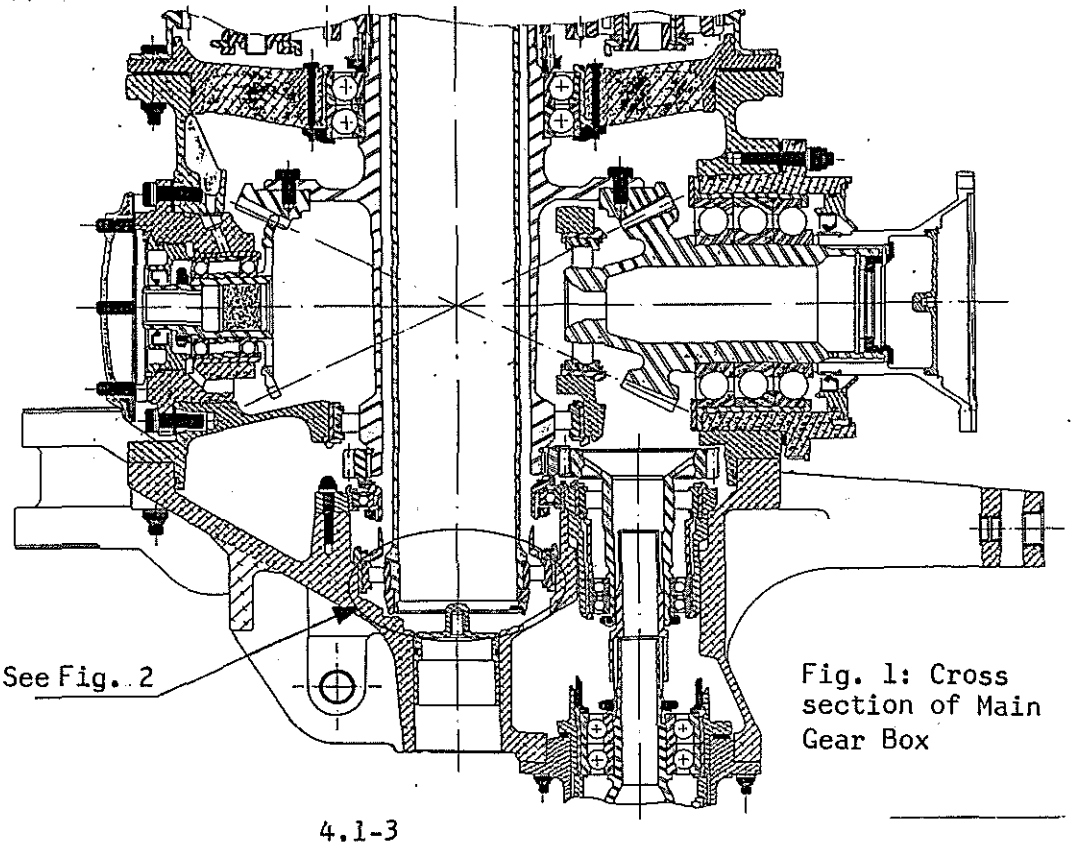


Fig. 1: Cross section of Main Gear Box

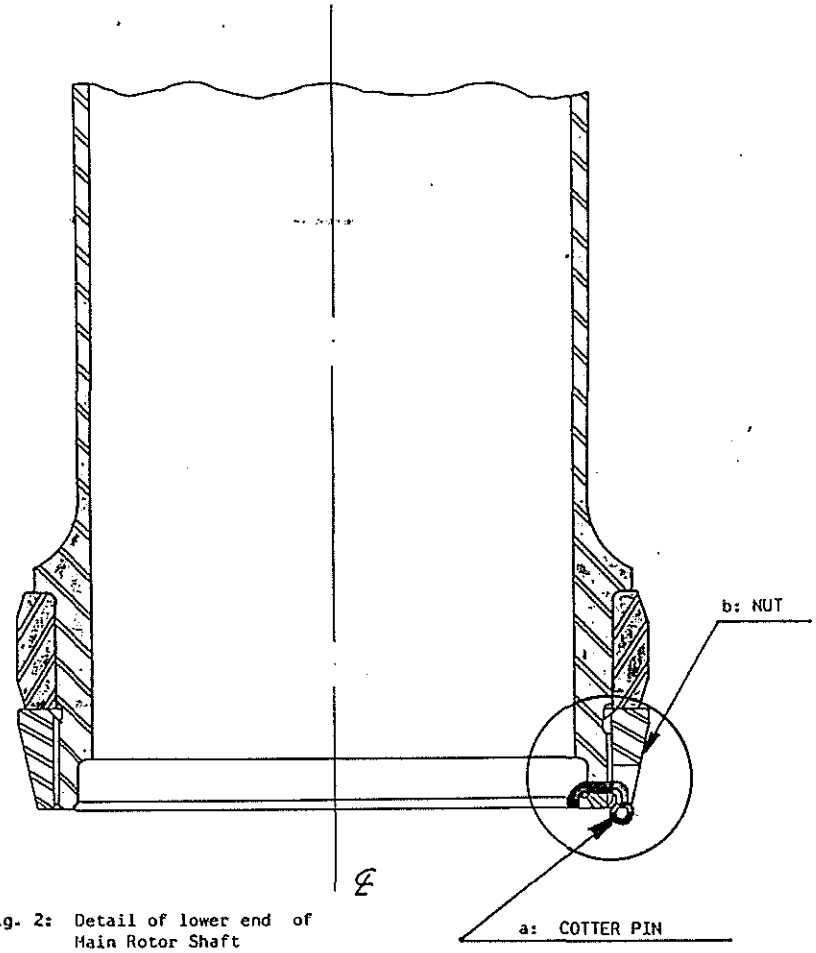


Fig. 2: Detail of lower end of Main Rotor Shaft

The sequence has been the following:

Step 1. Interference of the eye of the cotter pins (item a) with case wall.

Step 2. Failure of the cotter pins, after several flying hours with separation of the eye and loss of safety action.

Step 3. Loss of torque on shaft nut (item b).

Step 4. Interference of the nut with case wall and literally milling of the housing (see arrow on fig. 3)

Step 5. Obstruction of lubricating oil jets orifices.

Step 6. Partial loss of lubrication of the gear box.

Step 7. Braking action of the nut between main rotor shaft and gear box case.

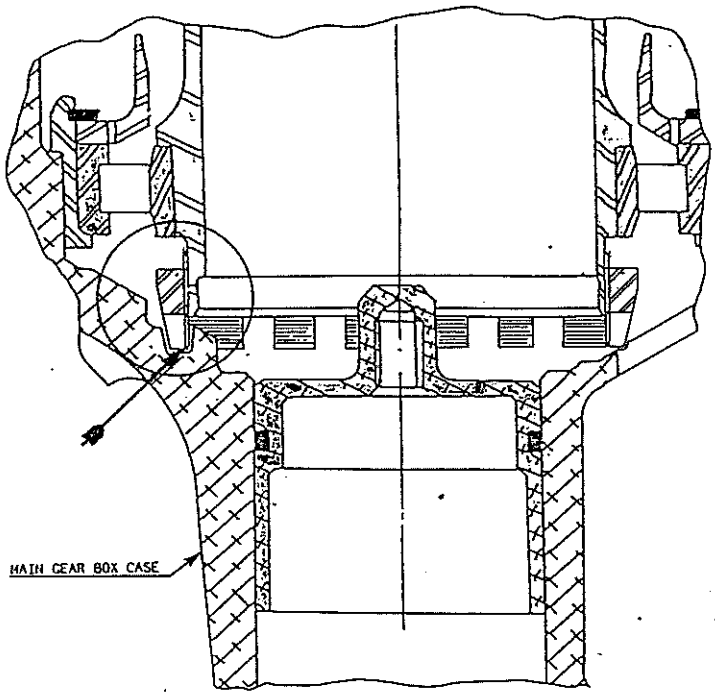


Fig. 3: Detail of Nut Main Rotor Shaft interference

Comments

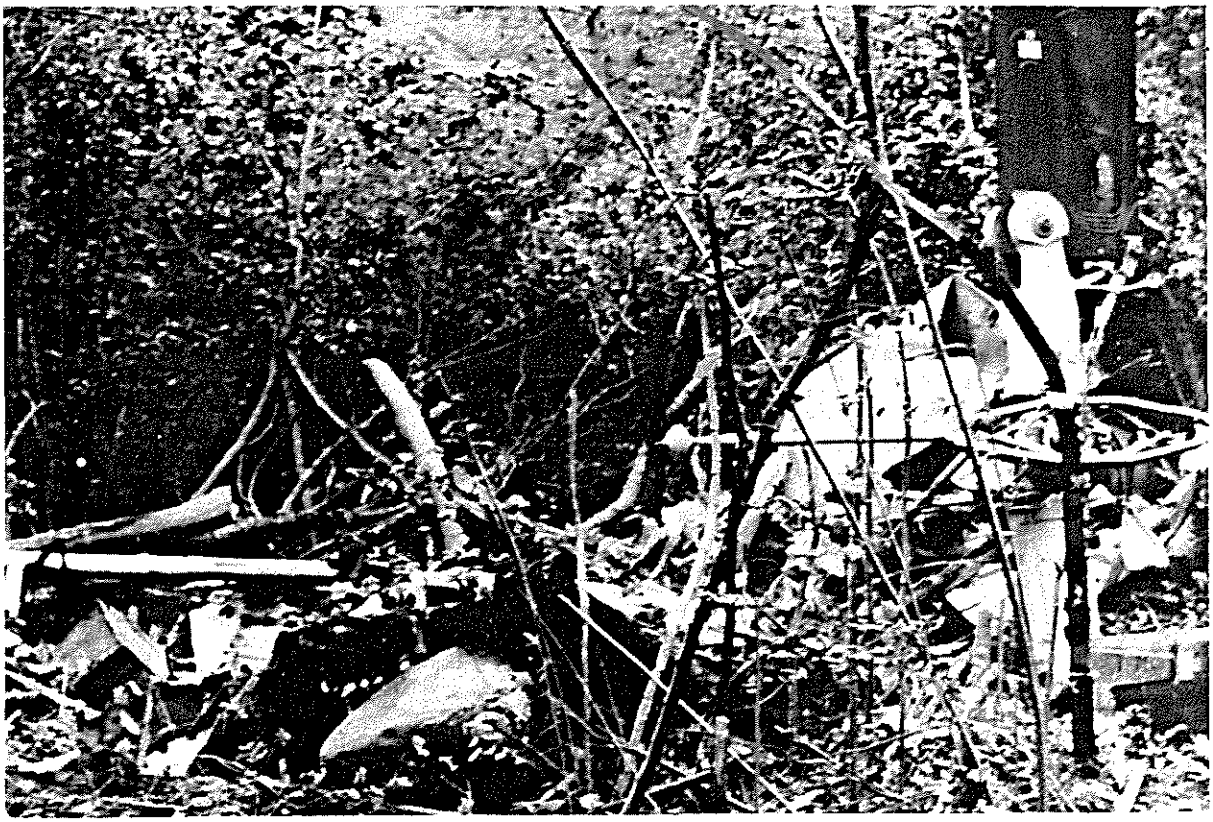
The case has been solved by the manufacturer expert in a very short period of time; if You realize how much an helicopter gear box is complicated and full of rotating parts, You can as well realize that dig out the true story is not so simple and easy.

CASE 2

The ghost cable

Description

During a training flight at low altitude on a wooded mountaineus region with four people on board, the pilot experienced the loss of directional control.
One crew member opened the sliding door in flying and confirmed to the pilot the stoppage fo the tail rotor blades.
An autorotation descent was initiated, ending in a survival crash landing for the occupants with distruction of the ship by the following fire.



Investigation

The Customer Investigation Board was not able to reach satisfactory conclusions on the probable cause of the accident. The most remote cause was the impact with a metallic cable because the flying region was familiar to pilots and copilots and they did not feel any impact.
After the formal ending of the Board proceedings, Agusta was invited to cooperate on the case.
Agusta experts, looking at the type of fracture seen on the tail rotor shaft, focused the attention on the 90° gear box.
The gear box was opened and disassembled in order to inspect the pattent of the bevel gear and pinions teeth.
Unusual pattents were found on the coast side of the teeth for a sector approximately 60° of the bevel gear.

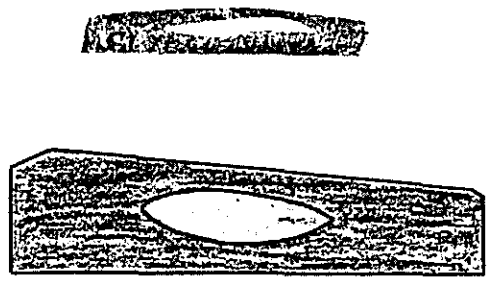


Fig. 4: Typical Gear Pinion teeth pattern.

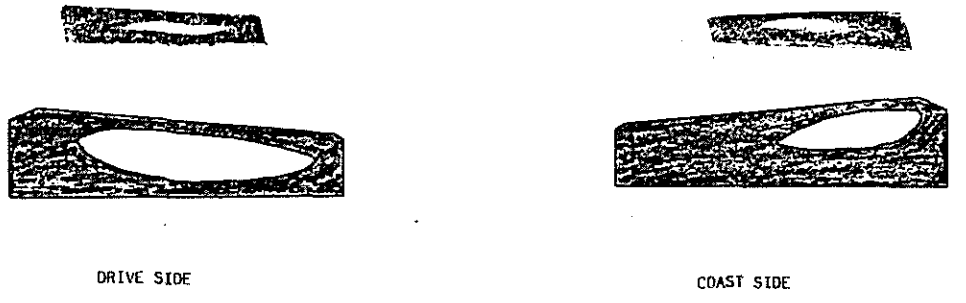


Fig. 5: Typical Bevel Gear teeth pattern

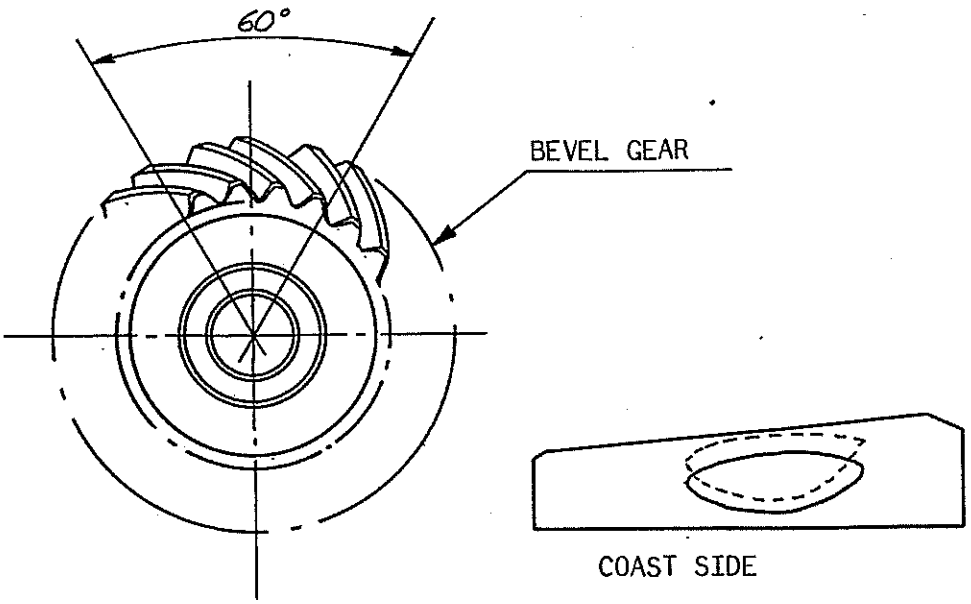


Fig. 6: 90° Gear Box Bevel Gear - Detail of Coast Side imprints

Only a super trained eye could realize that something had occurred to the dynamic components which slowed down the main rotor and made the tail rotor inertia forces load, on the apposite side, the gears.

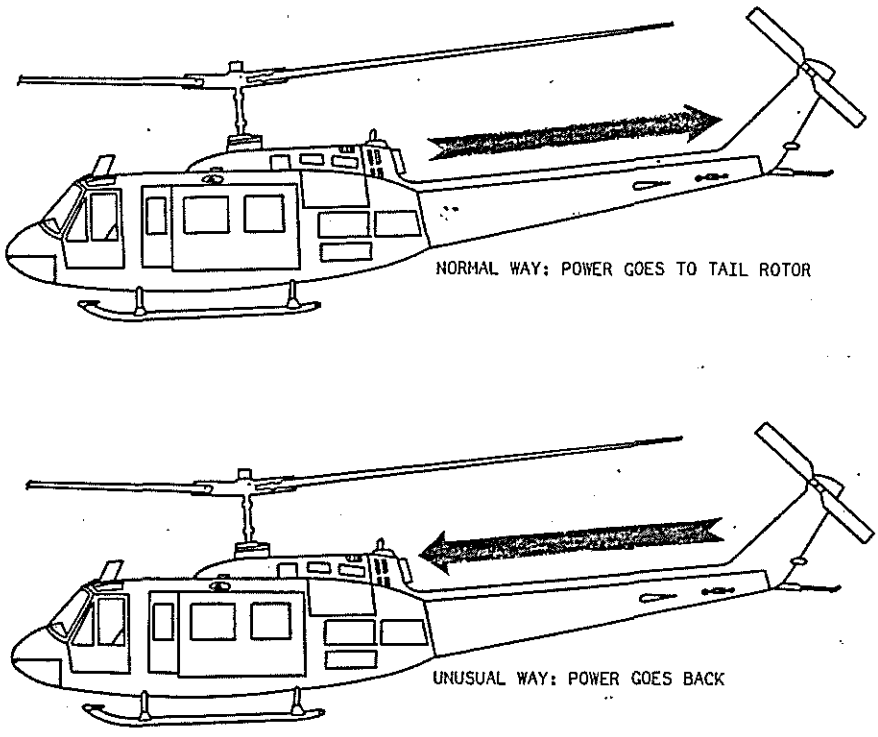


Fig. 7: Power Shifting

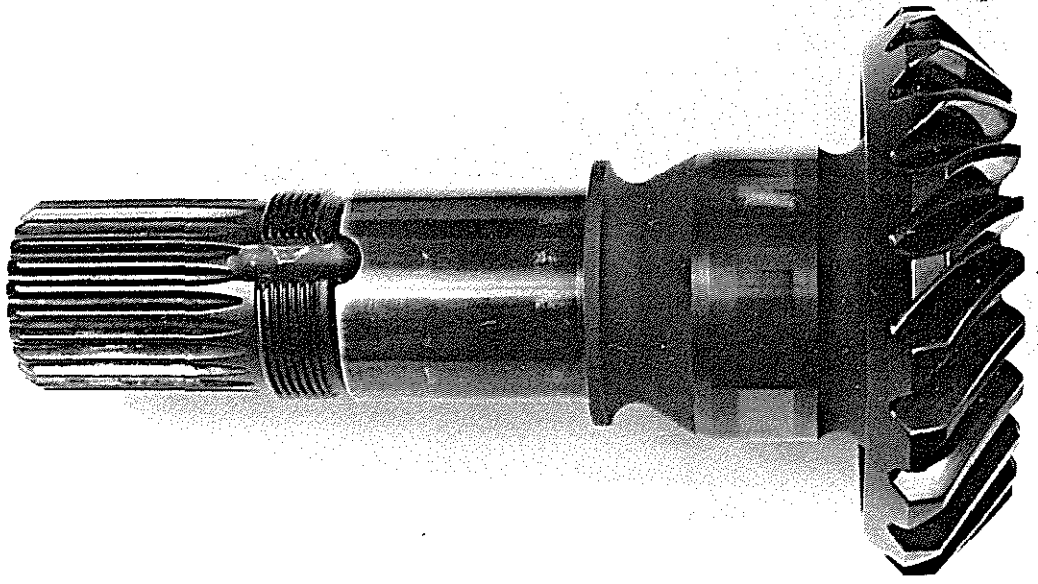
The formal investigation was reopened and, due to the very strong pushing of the Agusta experts, a wide research was initiated in order to seek, on the ground, between bushes and trees, the "ghost" cable.
It was found.
It was an illegal cable-vay built by a farmer to transport wood from uphill to the valley.

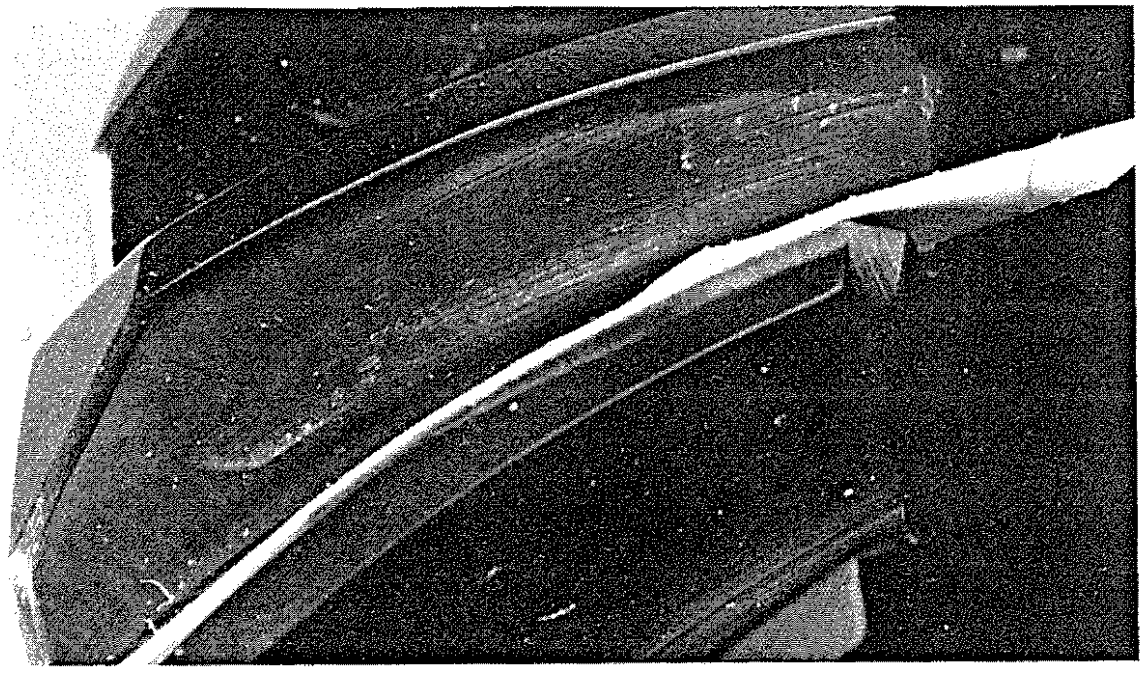
CASE 3

The story from the Manufacturer Data Bank

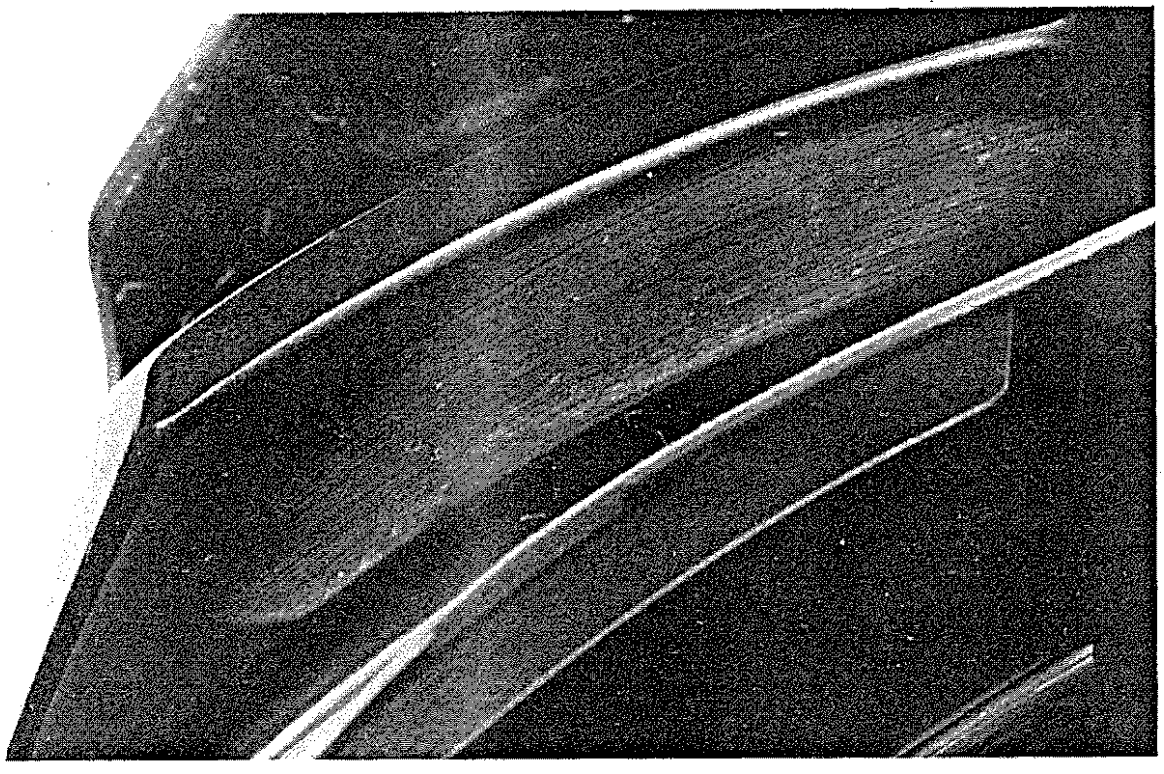
Agusta has accumulated a very valuable experience on the behaviour of its helicopters and components when, these components (gear boxes, hubs, blades, drive systems, etc...) are loaded by the different forces as in an accident. We believe that the following examples, taken from our investigation files, will explane, by them-selves, the importance of the manufacturer expertise.

1. Main Gear Box - Tail Rotor Imput Pinion





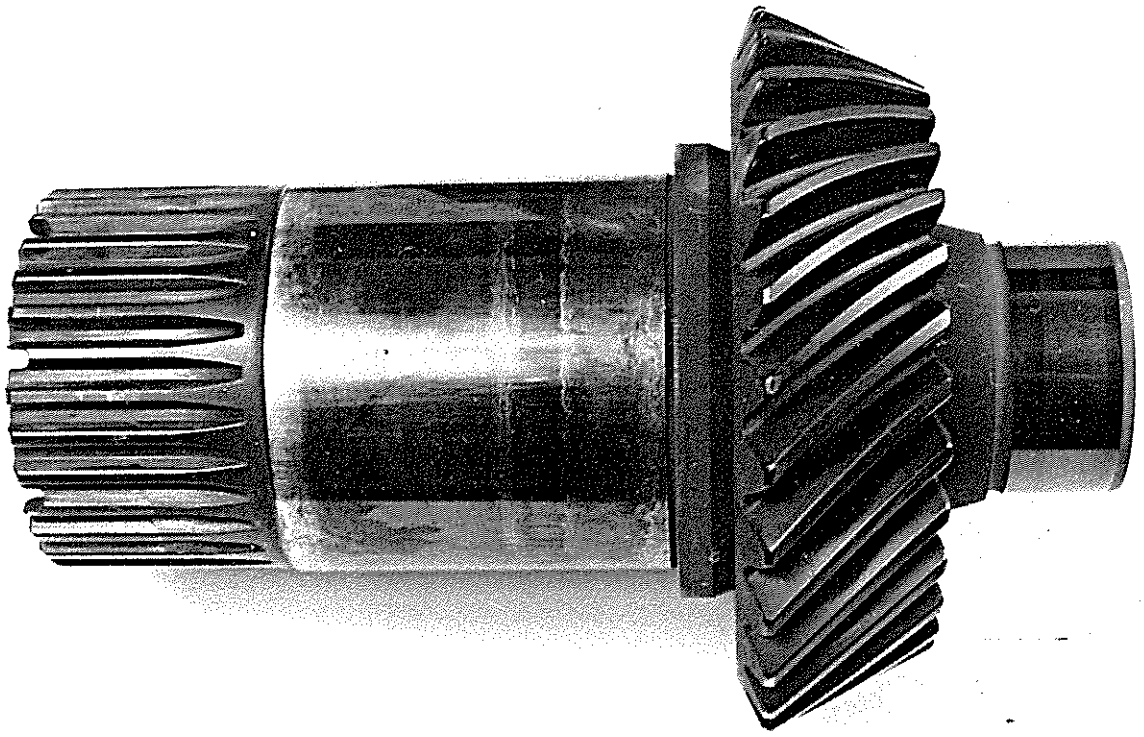
Tooth overstressed

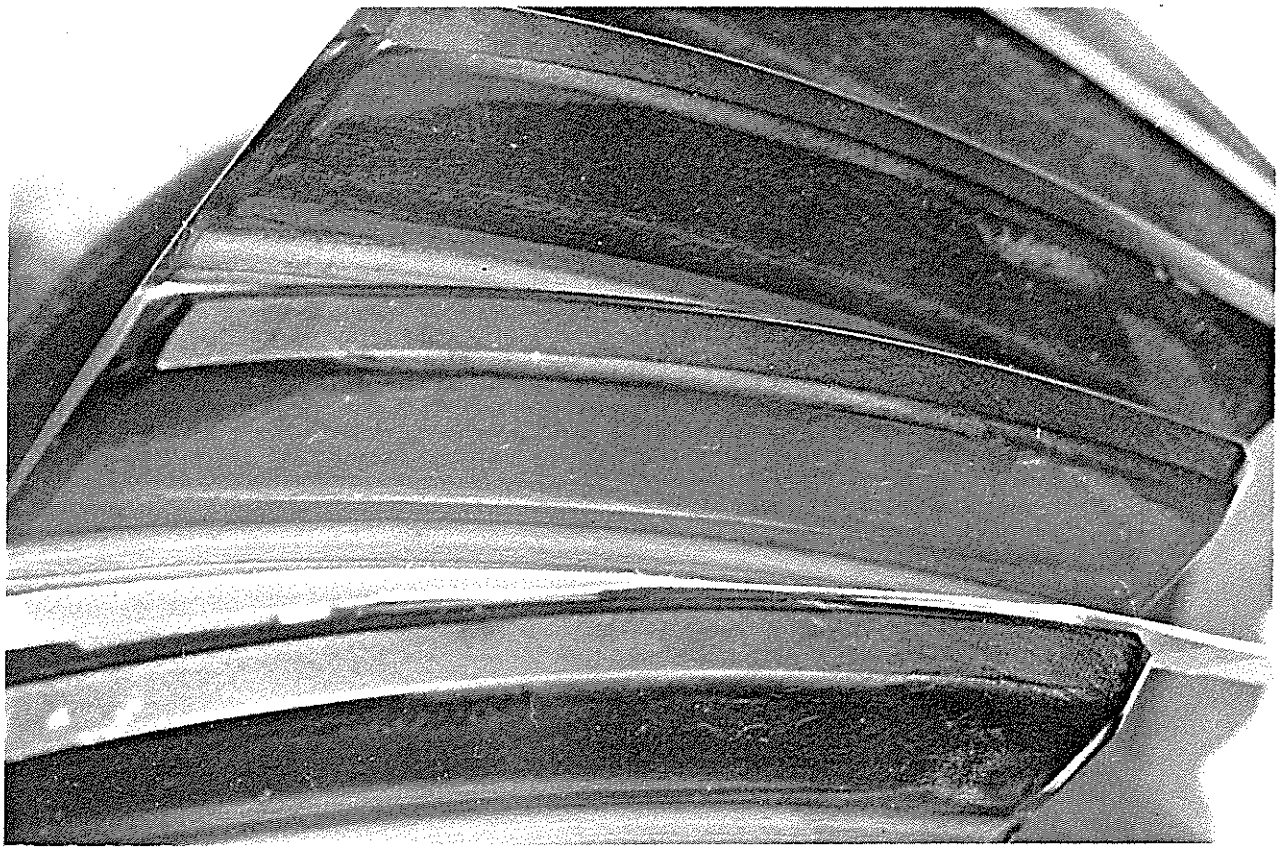


Normal pattern

The imprints, see arrow, show that a sudden very high load has been transferred from the gear box to the tail rotor system. This is the case when the tail rotor strike against foreign object. Of course the same know-how is used to show that no sudden stoppage if the tail rotor happened.
That was the case where Agusta was invited to understand why a tail rotor shaft failured in flight, leading to an autorotation landing and resulting in craft destruction.
Our thesis was that the probable cause being searched away from the tail rotor hitting with something and, it was found out that a forgotten maintenance tool, left between the shaft and the tail cone skin, litterally milled the shaft leading to the failure.

2. Main Gear Box Input Pinion





Normal pattern

The input pinion transfers the engine power to the main gear box.

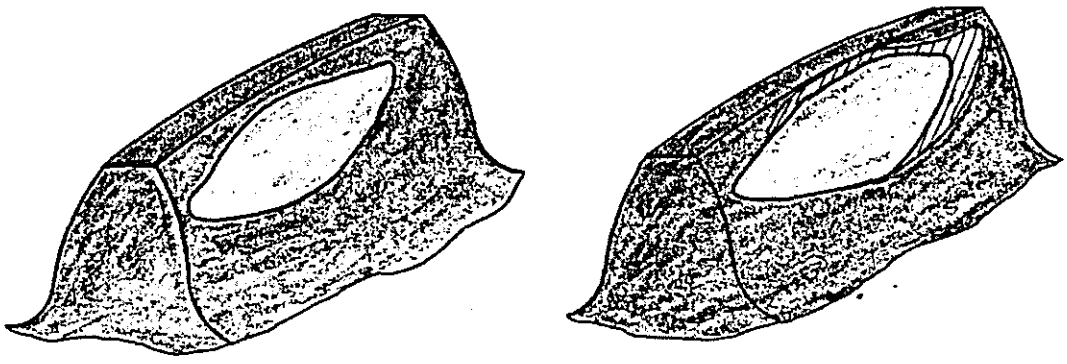


Fig. 11: Over Torque Pattern details.

The patterns indicate, in this case, that an over torque happened.
This can be evaluated by the shifting of the tooth pattern due to the higher level of stress on the gear and the housing; it can be seen as an additional pattern located out of the normal working position.

3. Swash Plate Assy

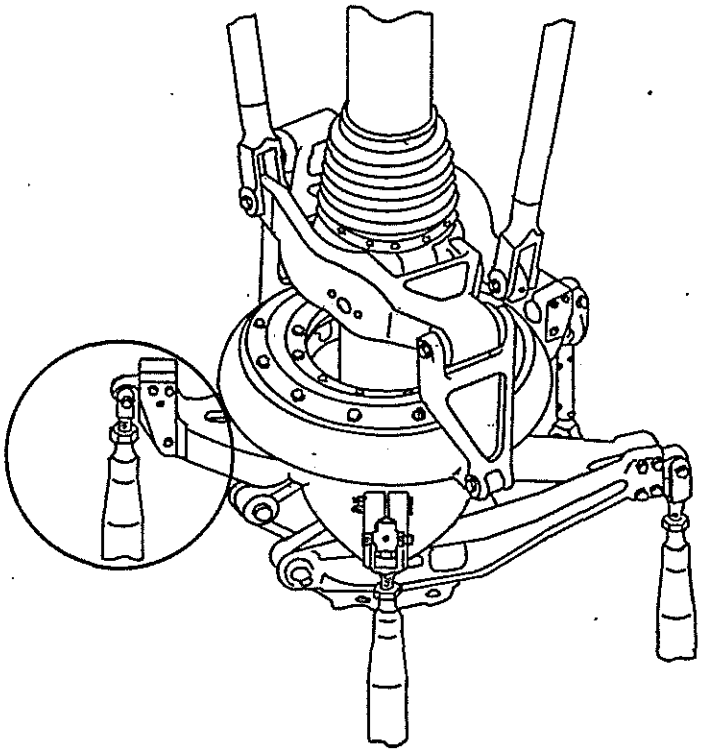


Fig. 12: Swash Plate Assy

The swash plate in the helicopter system, transfers pilot inputs to the main rotor.

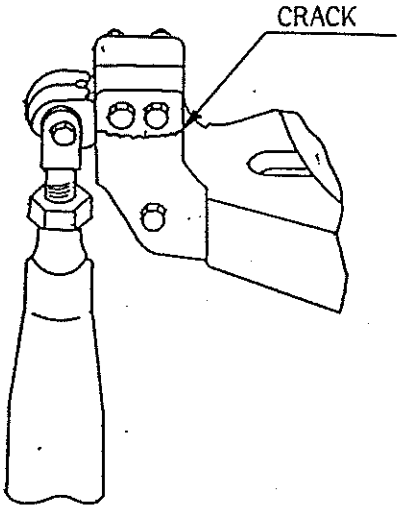


Fig. 13: Horn Lug before the Treatment

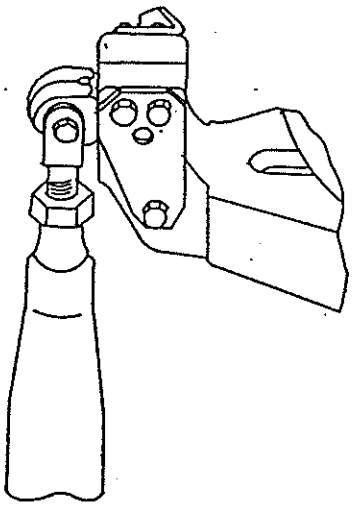


Fig. 14: Horn Lug after the Treatment

We experienced, in factory, during the assembly phase of swash-plate, a very strange failure of the horn-lug as indicated by the arrow, which kept Agusta experts puzzled for a while.
The horns were assembled with the trunnions and torqued according to the specs. without any problems; half a day later we could see clear evidence of failure, with loss of torque and therefore possibility of trunnion separation in flight.
I'll tell only the end of the story; we found out that the casting alloy aging naturally, became creep sensitive and the failure was classified as a creep failure for bending stresses.
A different casting material removed the problem.
We had no accidents, at that time but, for my experience, I am very sure that, in case an accident would have happened, no board could have provided data on the parts other than the Manufacturer itself.

Comments

The analysis of dynamic components, such as mating parts and gears is a very helpful method to understand what happened, but these findings can really be considered reliable if the evaluation is performed by specific experts who know every thing about that main rotor hub, main gear box or that specific system. We in Agusta say, making joke with those people, that the parts really talk to them.

CASE 4

Lubrication Oil Jets

Description

During a mission of trasporting troups, the pilot experien ced a slow reduction of main rotor speed even though the engine was increasing the power required for the horizontal flight. A sudden landing was made without particular problems; once on the ground, with power off, the main rotor decelerated very rapidly with abnormal noise coming from the main gear box.

Investigation

Ihe investigation was performed by Agusta after the accident The main transmission was removed and, when opened, was found an almost melting of main imput pinion teeth with the bevel gear.

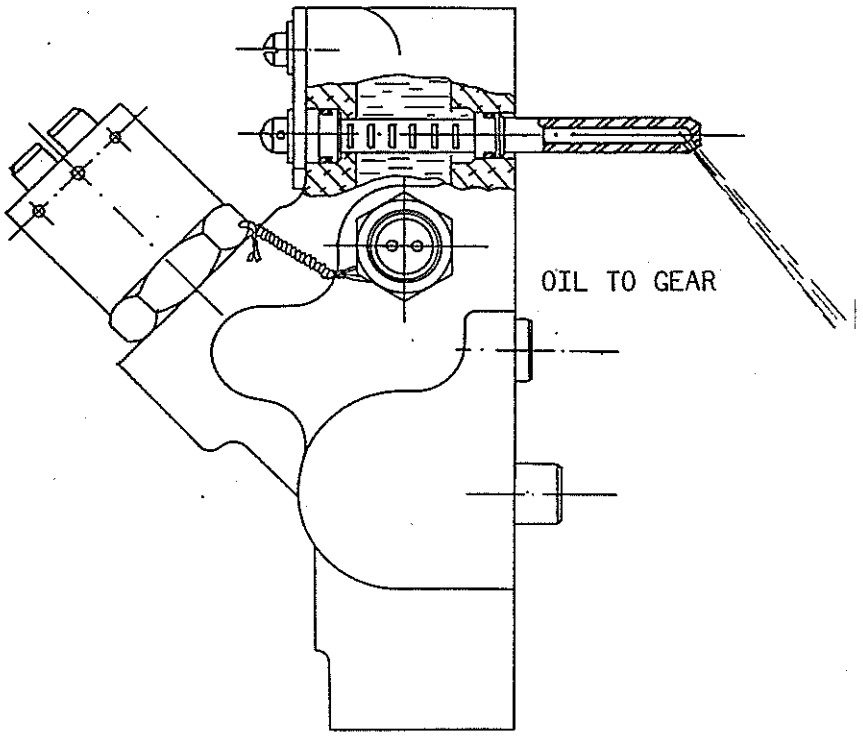


Fig. 15: Typical lubrification system

The mating gears were badly damaged, metallic parts were spread out all around the housing and many other elements suc satellities, such gear, bearings were damaged. Apparently there was'nt a clear evidence from where the thing started.

Our transmission expert however focused primary attention on the lubrication system of the gear box.
As many if You already know the lubrication of the transmissions are normally performed with oil passing through internal passages, built in during the casting phase of the housing, and oil jets having the purpose to direct a specific quantity of oil to a specific point.
Main culprit, for us, was a loss of forced lubrication of position n. 1 of main input pinion and bevel gear.
Based with the above firm belief the analysis of oil jet n. 1 revealed a failure.

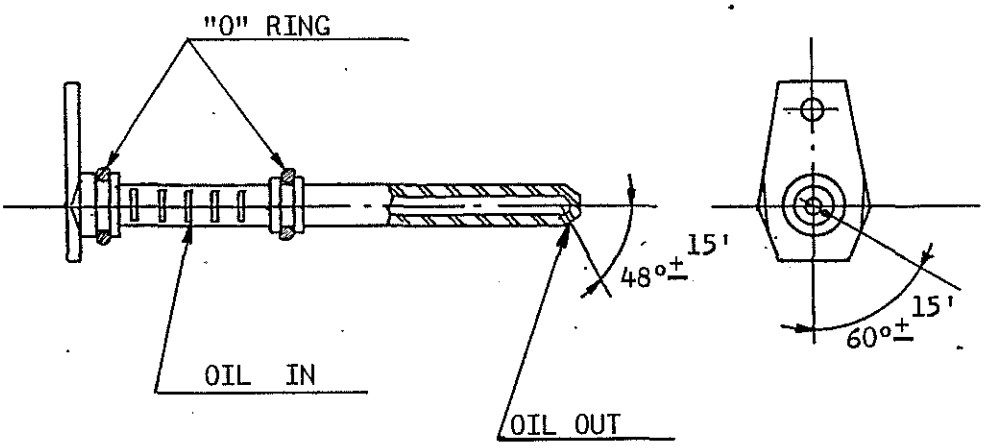


Fig. 16: Oil jet detail - Flow angle requirements

Oil jets are currently tested on target aim stand to check the accurancy of oil direction and oil flow.

What appened

Due the following reasons the head of the oil jet sepatated from the core, so permitting a slight rotation of the core itself with respect to the head, diverting the oil flow from the gears.

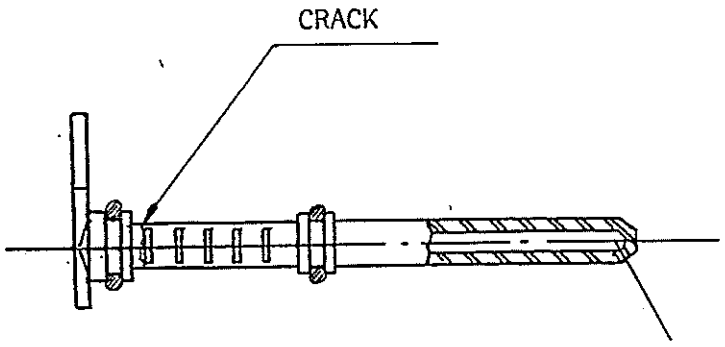


Fig. 17: Detail failure

Why did that happen?

The removal of the oil jets during the maintenance operations is permitted by means of two opposite chamfers milled on the head to bring the jet out of the case.

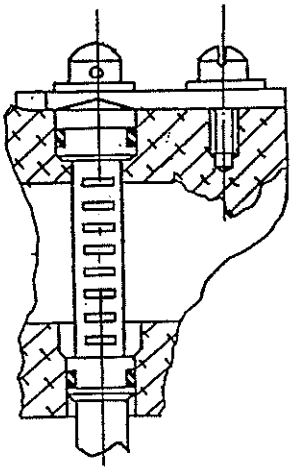


Fig. 18: Oil jet installation System

If You try to remove the jet with the use only of one screwdriver pushing from one side first and the, from the other, You stress for bending the oil jet in the cross section where the resistent area is very low for oil passages.
In our case we had a real fracture of the jet with the rotation as explained.

Comments

We honestly believe, in this case that a well prepared Investigation Board, apart from the Manufacturer, could reach the same conclusions on the cause of the accident, but two considerations are to be done to explain the importance to have, as soon as possible, the Manufacturer on board during an accident investigation:

- due to the great amount of data available by the manufacturer, the times required for the investigation can be drammatically reduced. The Manufacturer know, or he has to, the weak points of the components, in this case the sensivity to the loss of lubrication.
- Being part of the Investigation Board, the Manufacturer can know, with no delay, flying safety problems and therefore, with no delay, provide for corrective actions.

In this case the oil jet was modified prescribing to the Operators a different system of oil jet removal to prevent bending stresses.

Conclusive Comments

The cases presented above could certainly have been processed also by a Commission without the direct participation of an expert from the Manufacturer. However, in this case the investigation would have required a longer time and could perhaps have been completed only with the involvement of the Manufacturer at a later stage.
We are all well aware that timeliness in concluding the investigation is an essential factor.
Promptness in the determination of the causes, followed by an appropriate and timely corrective action will assiste in avoiding recurrence of the discrepancy condition.
After an accident it is for many reasons in the interest of all to find out the causes, but the stimulus of the Manufacturer to locate any possible technical cause is undeniable, in order for him to take the required immediate corrective action.
His name, image and turnover are adversely affected by an initial accident, receive a bad blow following a second accident and a deadly blow at a third...
The Manufacturer therefore is willing to provide the most extensive collaboration in assisting the other Commission Members in locating the causes of the accident, thus enhancing in the process the capabilities of the commission according to an international saying which reads "Many Hands Make the Work Light".

The author wishes to thank:

Mr. Luigi Colombo Mechanical Shop Chief Inspector

who greatly contributed to this paper providing an endless source of information.