SOME OBSERVATIONS ON FAILURES IN AIRCRAFT ENGINES AND FUSELAGE PARTS

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Introduction

Due to rapid development of world air transport, India has become the connecting link between the West and the Far East. There is a net-work of aerodromes in this country and during 1951 eight Indian Companies were operating scheduled services, internal and international, covering an unduplicated route mileage of 26,205. Though there are a few workshops to repair engines of civil aircrafts there was no firm to build aircraft in this country fr a long time. Pioneering work was carried out by the Hindusthan Aircraft Ltd., Bangalore, which is well equipped for quantitative production of aircrafts.

During last war Messrs Tata Iron & Steel Co. Ltd., manufactured aircraft steel to A.S.T.M. and B.S. Specifications. Considerablequantity of steel to SAE 4130 specification was supplied to Messrs Hindusthan Aircraft Ltd., formanufacture of U. S. army aircraft parts and spares. The steel was inspected and tested by the Government Metallurgical Inspectorate at Tatanagar. For approval of welders for aircraft work the Metallurgical Inspectorate carries out physical and metallurgical tests on welded samples forwarded by the Director General, Civil Aviation.

Though considerable amount of skill and attention is always paid in building and maintenance of modern aircrafts, some failures take place due to defective machining, faulty lubrication, error in fitting, defective material etc. Furthermore, engine parts, propellors, landing gears etc., are subjected under great strain-owing partly to the higher power and sudden change in running conditions. Several cases of failures of crank shafts, master rods, lugs in cluster joint from fuselage, fuel pump driving shafts, crank case, etc., were received from the Controller of Aeronautical Inspection for metallurgical examination.

Fatigue failures in aircraft:

Practically all fatigue failures originate at a surface, usually an external surface but occasionally at a surface of discontinuity of properties inside the material. Rough machining, nicks, cracks etc., produce local stress concentration which far exceeds the ability of the metal to withstand stresses when repeatedly applied. Metallurgical factors such as oxidation, decarburisation etc., may result in inferioı mechanical properties of the surface of the material and it becomes sensitive to fluctuating stresses.

In the case of fatigue failure of a crank shaft of an aircraft engine, the fracture face clearly showed the usual characteristics of fatigue failure starting from minute cracks on the journal. These cracks are suspected to be grinding cracks which acted as nuclei for progressive fracture to spread through one of the web causing complete severance of one of the journals from the crank shaft. The area ABCD in Fig. 1 showed typical fatigue fracture, associated with a small area of crystalline fracture, which failed under shock. This sort of failure may cause serious accident but in this case loss of oil pressure was detected on ground and the engine had to be stripped prematurely which revealed the failure of crank shaft. The chemical composition of the crank shaft is given below:

	Percent
Carbon	0.42
Manganese	0.78
Nickel	1.78
Chromimum	0.83
Molybdenum	0.25

The material confromed to A.S.T.M. Specification SAE 4130 and was properly heat-treated having uniform hardness of 430 VPHN. The crank shaft showed freedom from defects such as segregation of metalloids, inclusions, seams etc.

Two other cases of fatigue failures of fuel pump driving shafts in aircraft engines are illustrated in Figs.1 and 2. The waisted portion of the driving shafts showed clearly rough machine mark (Fig 1) and dents (Fig 2). Both the shafts were properly case hardened having hardness 890 VPHN on the case and 270 VPHN in the core. Chemical analysis of both the samples confromed to SAE 4320*. Machine groove and dents aggravated the stress concentration so as to bring about fatigue failure in both the shafts. Bright worn out square stud face marked R in Fig. 1 is indicative of looseness in fittings. The driving shaft was new and had done only 334 hours and 10 minutes before the failure took place. In both the cases the engine had to be dismantled before they were due for overhaul. Fig 3 illustrates the failure faces of Fig. 1. Areas ABC and XYZ in Fig 3 showed polished surfaces as a result of two faces of the crack rubbing together. The rest of the portions were crystalline due to sudden fracture.

Fig. 4 illustrates a welded cluster joint with broken lug from fuselage of an aircraft which was sent for metallurgical examination. The aircraft met with an accident as one of the wheel collapsed due to failure of lug fittings which was holding the under-carriage compression strut. Deep tool marks in the broken lug could be seen in Fig 4. The chemical composition of the lug conformed to SAE 4130 and was properly that heat-treated having uniform hardness of 270 VPHN. Microphotograph of the lug (Fig 5). showed grain distortion and a crack. The failure of the lug was probably due to heavy landing and was accentuated by the presence of deep tool marks which acted as stress raisers causing failure under shock. It is probable that cracks similar to XY in Fig5. might have developed in the lug before the actual failure took place during landing.

Failure due to lack of lubrication:

Aircraft bearings and other frictional parts need abundant and continuous flow of lubricant to reduce undue heating and wear. Usually oil pressure varies from 60/90 lbs per square inch. Lubrication failure may take place due to various reasons namely unclean filter, foreign matter in oil, carbon deposit in oil holes, rough operation during start and in air, inefficient lubricating pump, incorrect oil pressure gauge, etc. Failure of lubrication causes serious damage to aero-engines. A few cases of failure of master rods received for metallurgical examination were attributed to the break-down of lubrication. Fig 6 illustrates a broken master rod belonging to an aero-engine. The chemical composition of the master rod conformed to SAE 4340 and the material was uniformally heat-treated, having hardness of 321 VPHN. Lubrication failure caused complete melting of the bearing metal from the split bush and some of the molten metal choaked oil holes in the bush marked X & Y in Figs. 7 and 8. Absence of bearing metal in the bush caused constant hammering action of the big-end on crank shaft. In all probability the master rod failed due to severe knocking, but the severe damage shown in Fig. 6 was caused afterwards due to rotation of crank shaft by other engines.

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* SAE 4320: C

Failure due to defective material:

Though several non-destructive methods such as X-Ray, magnaflux, fluorescent liquid, supersonic wave etc., are used for inspection of ferrous and non-ferrous aircraft engine parts and other important components in fuselage, defects both on surface and internal have escaped detection. A number of cases of failures of crank case in aircraft engines were sent to the Inspectorate for investigation. Cracks took place in the aperture for mounting the fuel pump and oil leakage was detected after 500 to 700 hours engine run. The crack is seen in Fig 9, marked AA. The temperature of the oil was not allowed to exceed the maximum temperature permissible. Some engines are prone to undue vibrations for a short period during shutting down. Fig 10 shows the fractured face of the crank case with undesirable porosity and sectional changes. The chemical composition of the case was as follows:

		Percent
Copper	...	1.21
Magnesium	...	0.35
Silicon	...	1.75
Nickel	...	1.29
Iron	...	1.22
Titanium	...	0.14
Zinc	...	0.22
Aluminium	...	Balance

The crank case conformed to specification—RR-50. The failure of the material was attributed to casting defect, and to the propagation of cracks from the shrinkage cavities. The propagation of the crack was caused by undue vibration of the engine.

ACKNOWLEDGEMENT

The authors desire to express their thanks to the staff members of the Inspectorate for their help in the preparation of this note. Our thanks are also due to the Director-General (Supplies & Disposals), Government of India, Ministry of Works, Housing & Supply, for his permission to present this paper at the symposium.

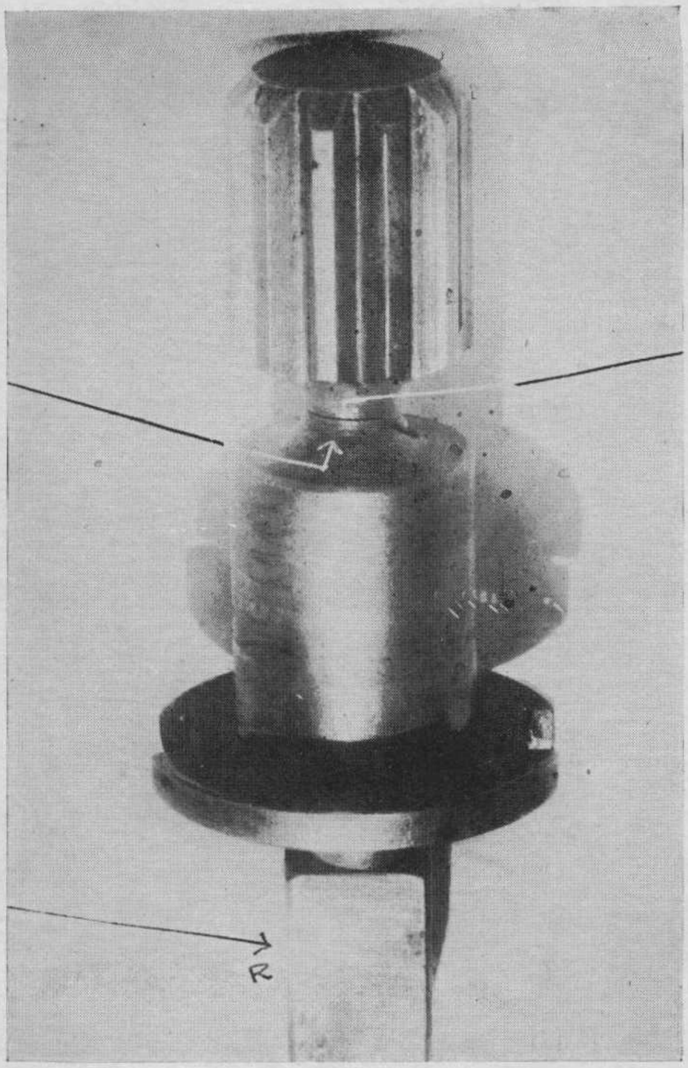

FIG. 1. Photograph showing the line of fracture and deep tool mark at the waisted portion of the drive-shaft of the aero-engine fuel pump. X4

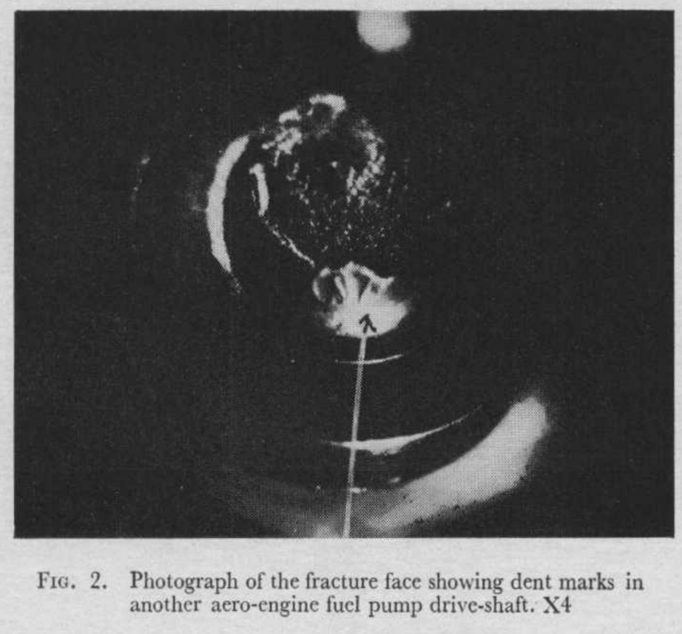

FIG. 2. Photograph of the fracture face showing dent marks in another aero-engine fuel pump drive-shaft. X4

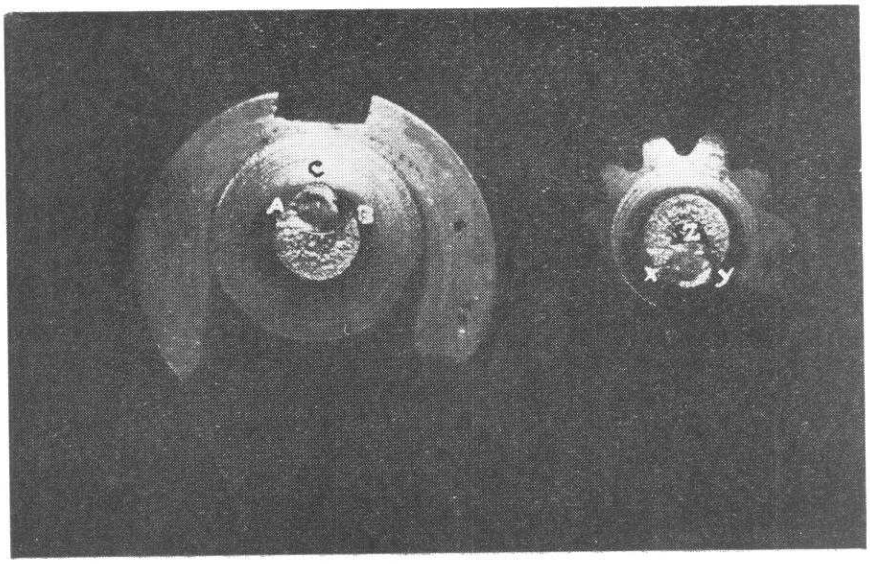

FIG. 3. Fracture face of Fig. 3 showing fatigue failure.

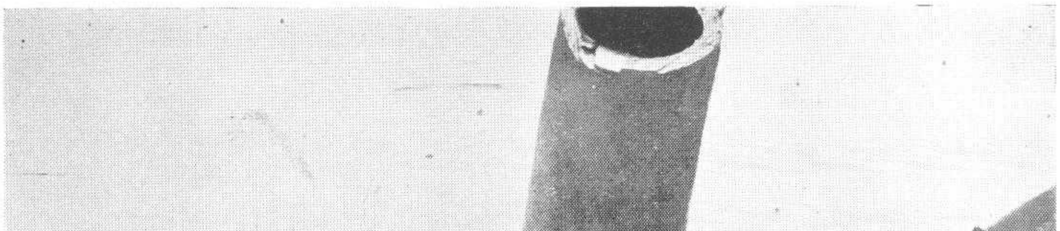

FIG. 4. The cluster joint with broken lug.

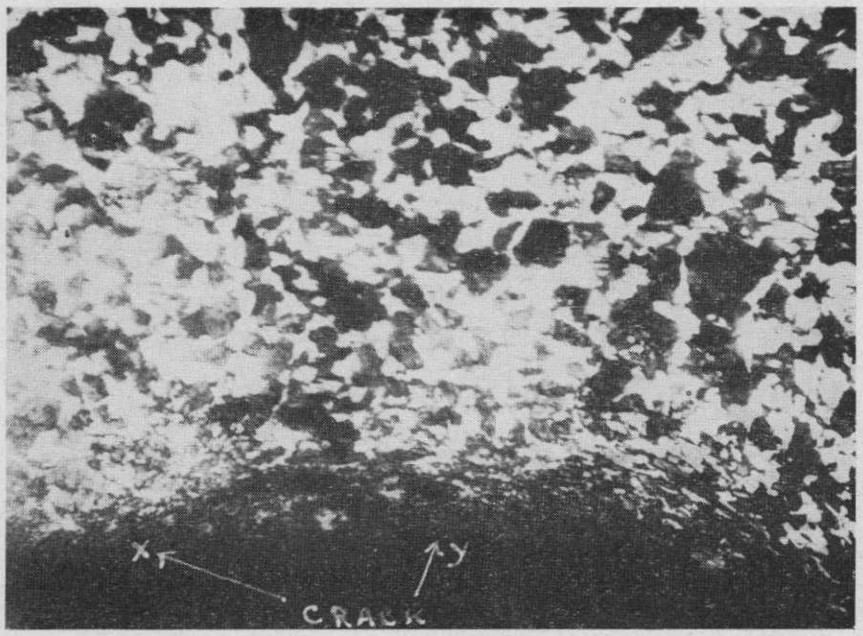

FIG. 5. Photomicrograph of the broken lug showing grain distortion and crack.

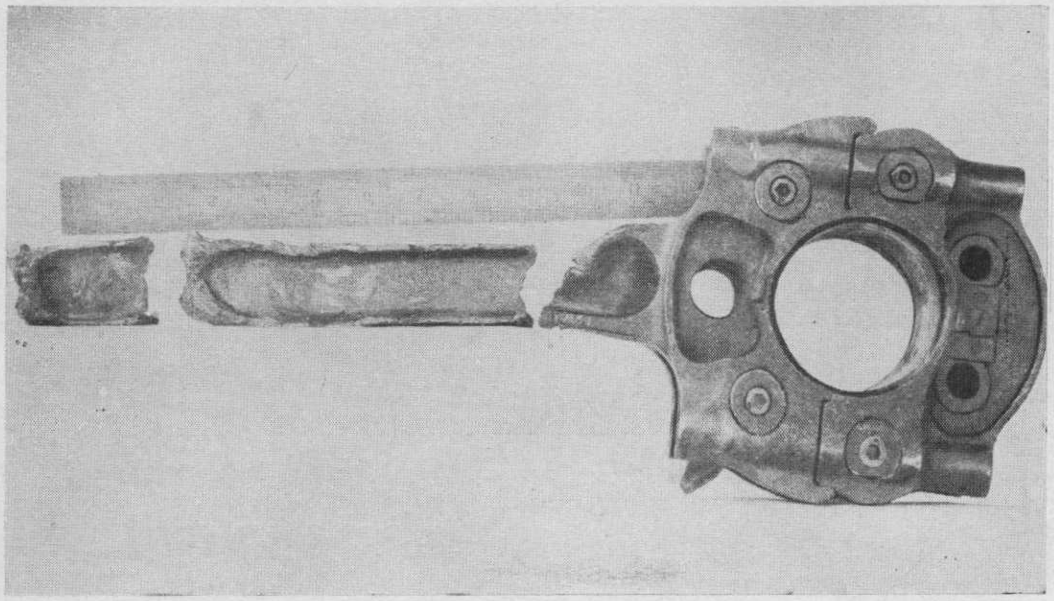

FIG. 6. Pieces of the broken Master Rod of an aeroengine as received.

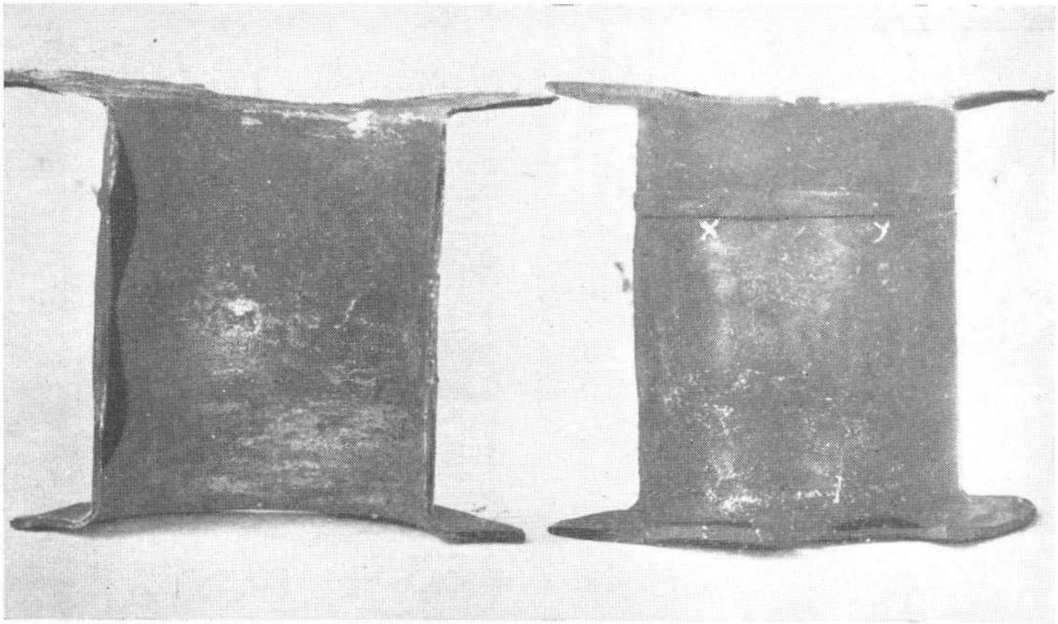

FIG. 7 Shows split bust with oil holes closed.

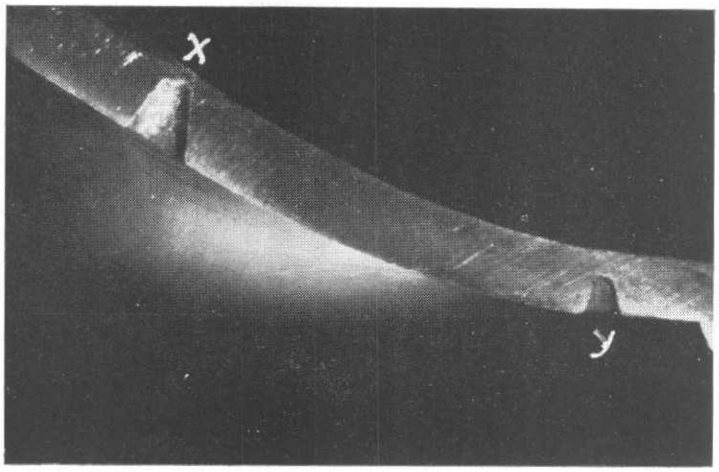

FIG. 8. Macro photograph of a section through the bearing bush showing oil holes closed.

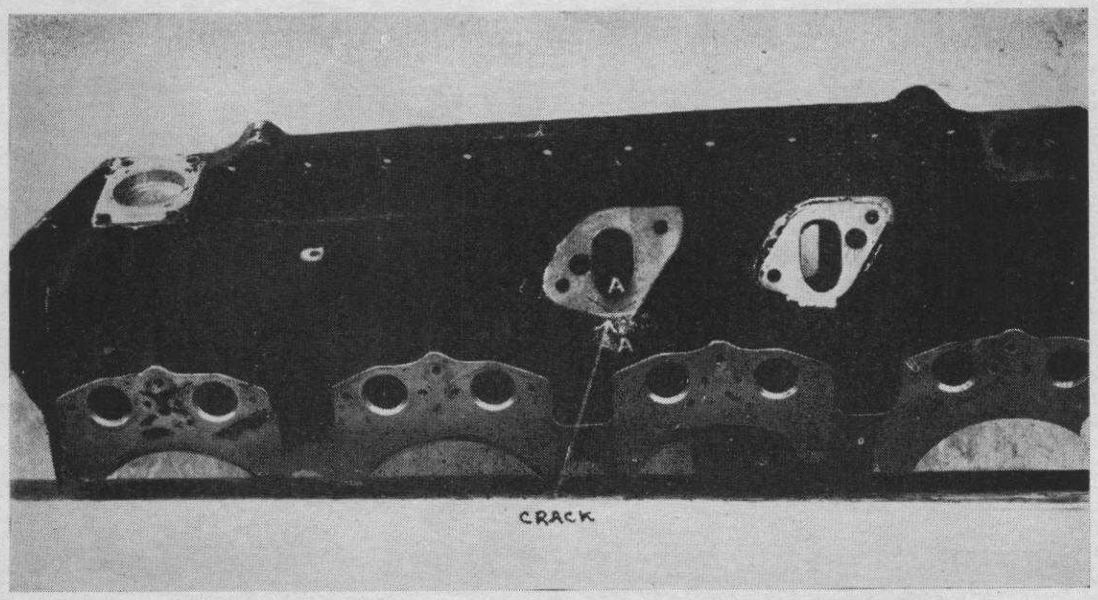

FIG. 9. Photograph of an aircraft crank case showing the position of crack at the fuel pump aperture.

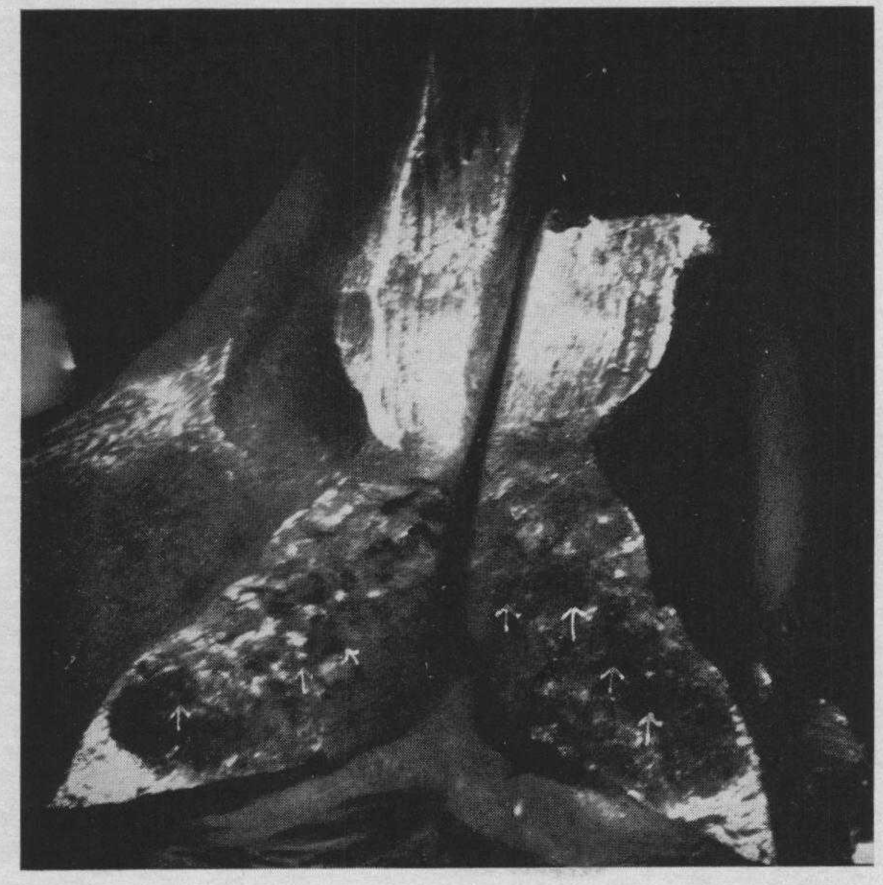

FIG. 10. Photograph of the fracture face of the fuel pump aperture showing porosity (shown by arrows). X2.5

DISCUSSION

Mr. R.A.P. Misra:

Would Mr. Dey please confirm that the fuel pump shaft which had failed, was case-hardened in the neck when failure occurred? As a rule, case-hardened parts fail through fatigue if grossly overloaded or if there are hardening or grinding cracks present on the surface.

Mr. De:

In this particular case, there were tool marks on the material. The material had properly been case-hardened at the tool marks. The looseness in the fitting had caused the fatigue failure. It was case-hardened all through.

Dr. Nijhawan:

Commenting in general, on the performance of air-craft materials he stated that before being put into commission, possibilities of fatigue failures of aircraft components have to be carefully considered in relation to the materials employed and operating service temperature requirements. Most physical tests are determined at room temperatures, but in the case of 'Comet' aircraft which is flying 7-8 miles up at a temperature of-20-to-30° C., the requirements of physical properties of materials employed for certain components, such as wings, fuselage, etc., at the prevailing sub-zero temperatures will be most rigid. In the case of high temperature materials, other factors to be reckoned with, besides the creep strength, are the corrosive action of exhaust gases and lubricants used. In the case of air-craft materials, the failure studies are quite complex and are related to numerous varibles, possible effects of which have to be systematically scrutinized.