ZBIGNIEW KORCZEWSKI, D.Sc.,M.E.
Polish Naval Academy, Gdynia
Institute of Construction
and Propulsion of Vessels

Endoscopic examination of naval gas turbines

The paper presents application of endoscopy in diagnosing the naval gas turbines. Selected results of such examinations with the use of fiberocopes, carried out on the turbines installed on the Polish Navy vessels are included.

INTRODUCTION

Permanent modernization and extending abilities of the measuring-diagnostic systems applied to naval gas turbine power plants make it possible to widen the range of the control system functions by including, apart from standard service parameter measurements, also recording and forecasting functions of engine's technical state.

Contemporary naval engines are fitted with more and more effective measuring-control systems to record engine load parameters. Nevertheless serious engine failures still happen in service, caused e.g. by excessive vibration, loss of coaxiality of rotating elements, failures of blades or rotor disks, which had not been identified earlier [3].

Difficulties of identification of failures occuring in the gas turbine flow part with the use of the changes of thermo-gas-dynamic parameters of working medium, are connected with an appropriate interpretation of the defect symptoms which are often recognized as engine tear-and-wear symptoms determined by its service operation time. External signs in both the cases usually are similar and difficult to univocal identification. A special case is the diagnostic parameter analysis for fouling intensity assessment of rotor flow passages as well as of effectiveness assessment of their washing. A typical erroneous interpretation of diagnostic symptoms is interpreting the service fouling state as the continuous process accompanying engine's service at sea, instead of its unserviceability state caused e.g. by partial burning of the turbine rotor blade tips. It can result from too late or ineffective washing of the engine flow part.

Similarly it is difficult to assess the engine state on the basis of operation parameters when the combustion chamber fails. Often the temperature distribution fields of exhaust gas vary only slightly, but the fire pipe is found burnt due to injector's failure.

New diagnostic examination methods are more and more common in gas turbine exploitation. Endoscopy, earlier used only in medical practice, dynamically developes and serves as a very useful tool for assessing the technical state of gas turbines [1,2,4].

Endoscopy is a disassembling – free method of visual-optical examination of internal spaces of machines and facilities with the use of speculum devices (endoscopes).The end of an endoscope (fiberoscope or boroscope) is introduced into special inspection holes or assembling openings for engine parts. The fiberoscope operation scheme is shown in Fig.1.

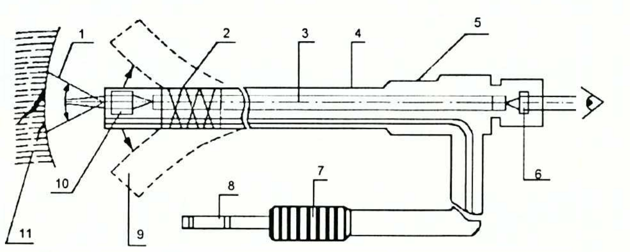

Fig.1. Fiberoscope operation scheme : 1 – observation sector, 2- endoscope end, 3 -imaging light-pipe, 4 – elastic element , 5 – control-regulation element, 6 – eyepiece, 7 – connecting member, 8 – light source connector, 9 –deflection sector of endoscope end („up-down", „left-right"), 10 – object lens, 11 – rotor blade with a micro-crack on the ege of attack

DESCRIPTION OF ENDOSCOPIC EXAMINATION METHOD

The Institute of Construction and Propulsion of Vessels, Polish Naval Academy, has OLYMPUS IF8D4-15 fiberoscope and G080-055-090-55 boroscope at its disposal (Fig.2) which make it possible to examine visually and take photos of engine internal spaces.

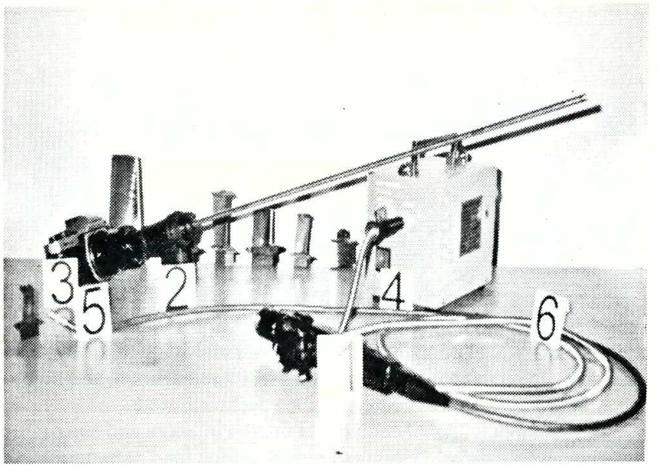

Fig.2. OLYMPUS diagnostic endoscope set : 1 – fiberoscope, 2 – boroscope, 3 – photo camera, 4 – light source, 5 – imaging light-pipe, 6 – supply light-pipe

The fiberoscope can be introduced through the inspection holes of the diameter greater than 8 mm. Its elastic light-pipe is 1500 mm long. It has the replaceable ends which allow for observations within 60° and 80° face sectors and 80° side sectors. Especially the side-view eyepiece makes it possible to quickly and effectively assess technical state of the edge of attack and trailing edge of both fixed and rotor blades.

The boroscope of 550 mm stiff lens system and 8 mm diameter makes visual examining within 80° side sectors possible. It has limited penetration abilities, but, being much simpler in use it is especially useful for onboard engine inspection.

Examining the gas turbine flow part by using the fiberoscope is realized through special inspection holes and hatches. Assembling holes of injectors and thermocouples can be also used.

An assessment method of technical state of the naval gas turbines in service with the use of endoscopy was elaborated on the basis of multi-year diagnostic investigations [4]. A necessary scope and schedule of engine internal space examinations, making it possible to find defects of engine flow passage, was established in result of systematic surveys carried out on three different types of naval gas turbine engines (DR76, DR77 and DE59). Detail guidelines for diagnostic examination with the use of fiberoscope and boroscope was elaborated [3].

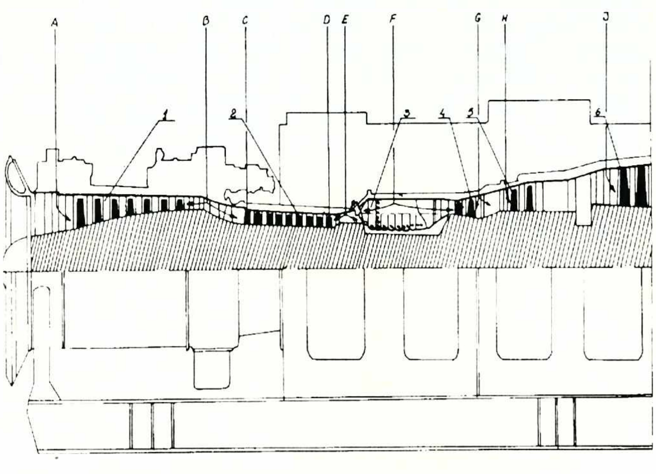

Fig.3. Endoscopic examination scheme of DE59 gas turbine : 1 – Low pressure compressor (LPC), 2 – High pressure compressor (HPC), 3 – Combustion chamber (CC), 4 – High pressure turbine (HPT), 5 – Low pressure turbine (LPT), 6 – Power turbine (PT), A – access to 1st stage fixed and rotor blades of LPC, B – access to 7th stage rotor blades of LPC through a technological hole in engine casing, C – access to 1st stage rotor blades of HPC through HP rotor earthing hole in engine casing, D – access to 9th stage rotor blades of HPC through HP rotor earthing hole in engine casing, E – access to the last-stage rotor blades of HPC and CC fire pipes through a measurement stub pipe, F – access to injectors and 1st stage of HPT through holes for locking devices of fire pipes in CC casing, G – access to 2nd stage of HPT through thermocouple assembling holes, H – access to 1st stage of LPT through a technological hole in engine casing, J – access to PT rotor blades through measurement stub pipes of engine casing

The endoscopic examinations should be carried out in the following situations:

- during profilactic surveys (at least once a year)
- during assessment of engine technical state when extension of between-repair period is necessary
- in the case of excessive vibrations, metal filings disclosed in oil, disturbed temperature distribution field of exhaust gases, drop of power, excessive smoking, checking the results of flow passage washing etc.

The disclosed defects are photographically recorded to file them in a computer data base and establish their trends.

In Fig.3 a cross-section of DE59 gas turbine with marked spots for examining the engine's flow passage is shown as an example.

Disassembling places to make examination holes open are exemplified in Fig.4 and 5.

Application of endoscopy to gas turbine diagnosing makes it possible to considerably shorten the overhaul and repair time. It also allows, if examination results are satisfactory, to extend the engine between-repair period of operation even by 20 to 25 % [3].

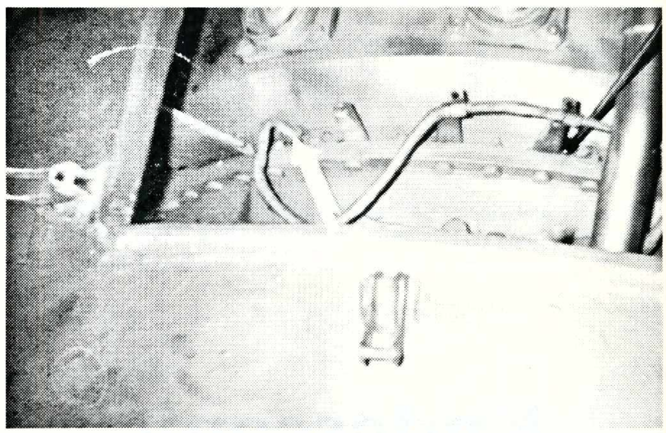

Fig.4. Access place to 1st stage blades of LPC of DR77 engine

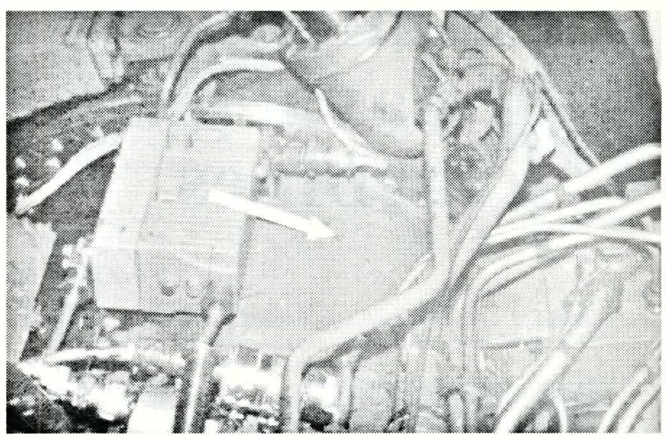

Fig.5. Access place to 2nd stage blades of HPT of DE59 engine. Through the assembling hole of the thermocouple

RESULTS OF EXAMINATIONS

The endoscopic investigations carried out during periodical prophylactic surveys of naval gas turbines in service demonstrated that the method was very effective and operation of the applied instruments was relatively easy. Many defects of the flow passage elements, which could be dangerous in the case of their uncontrolled growing, were disclosed in result of the examinations in question.Detail description of the disclosed defects can be found in the relevant yearly reports [4]. The most frequent defects of the flow passage elements of the examined gas turbines are presented in Table. Some of the recorded defects are shown in Fig.6 to 14.

Typical defects of flow passage elements, identified during endoscopic examinations of DR76, DR77 and DE59 gas turbines [4]

Examined element	Identified defect	Service recomendations
Rotor's and fixed blades of compressor	• fouling, soot and sea salt deposits (Fig.6) • mechanical failures: scratches and dents, traces of jamming the rotor in the casing (Fig.7 and 8) • cavities, pull-outs and cracks on the blades	• wash the engine flow passage • consult a decision on further engine exploitation with engine producer • stop engine operation
Rotor's and fixed blades of turbines	• combustion product fouling on blade surfaces • salt fouling of cooling ducts - obstructed deflector channels (Fig.13) • partly burnt and broken blade tips of trailing and attack edges (Fig.9) • surface bulges („blisters"), erosion pits at blade back planes and troughs (Fig.10) • damage of blade protection coating (Fig.11) • increased radial clearance of the turbine rotor with traces of jamming (Fig.14)	• wash the engine flow passage • as above • consult a decision on further engine exploitation with engine producer • consult a decision on further engine exploitation with engine producer, if a number of the surface bulges of Φ > 1 mm and h > 0.5 mm exceeds 1 per square centimeter • consult a decision on further engine exploitation with engine producer • as above
Combustion chamber	• carbon deposit layer on the swirler blades (Fig.12) • carbon deposit layer on face surface of injector cap • fire pipe burn-throughs, cracks and deformations	• up to 20 % of active flow cross-section area : wash the engine flow passage, over 20 % : disassemble the fire pipe and remove the deposit • disassemble the injector, remove the deposit by using a wooden blade (after soaking it in petrol or diesel oil), dry it in compressed air • consult a decision on further engine exploitation with engine producer

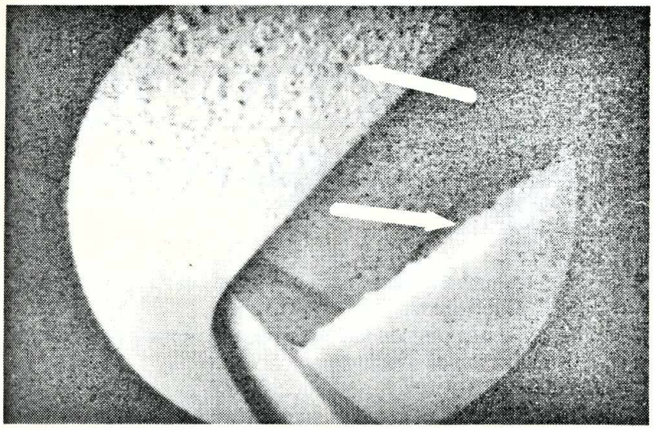

***Fig.6.** The 1st stage fixed and rotor blades of LPC of DR77 engine. Fouling deposits on the blades' surfaces*

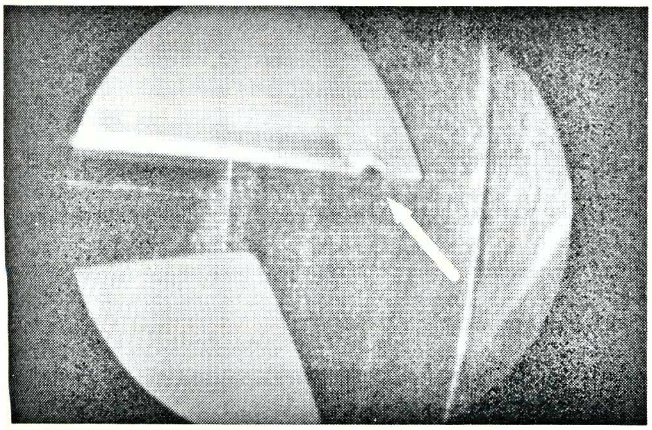

***Fig.7.** The 1st stage rotor blade of HPC of DR76 engine. A dent on the edge of attack, close to the blade tip*

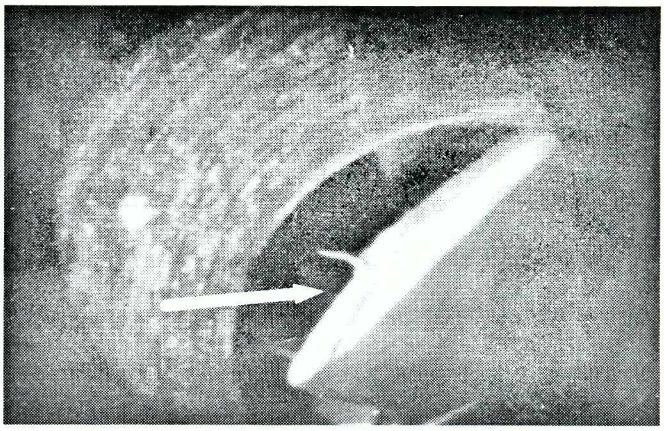

***Fig.8.** The 1st stage rotor blade of HPC of DE59 engine. Jamming traces on the blade tip edge*

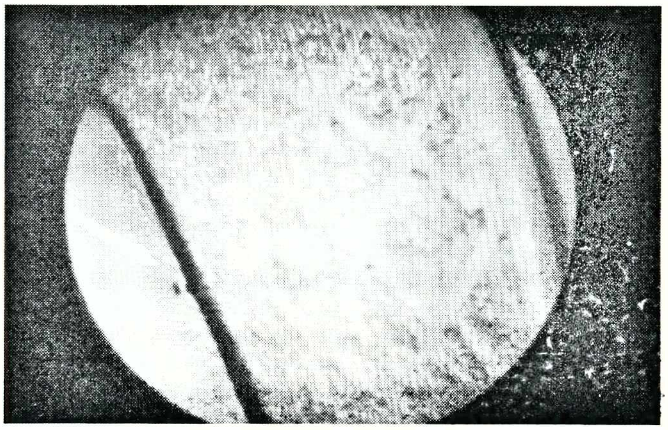

***Fig.9.** The rotor blade of HPT of DR77 engine. Partly burnt and chipped tip edge*

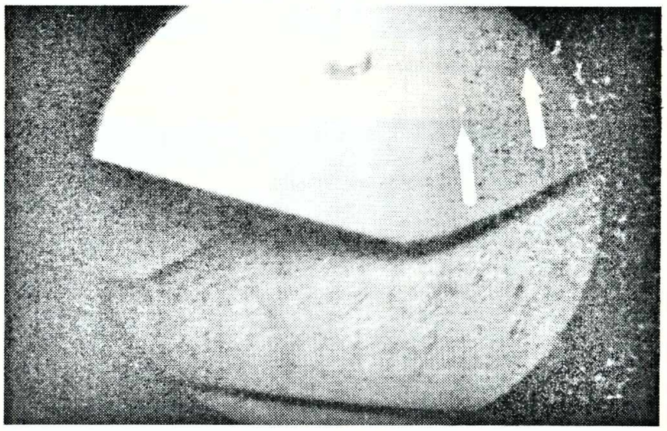

***Fig.10.** The rotor blade of HPT of DR77 engine. Surface bulges („blisters") at the blade back plane*

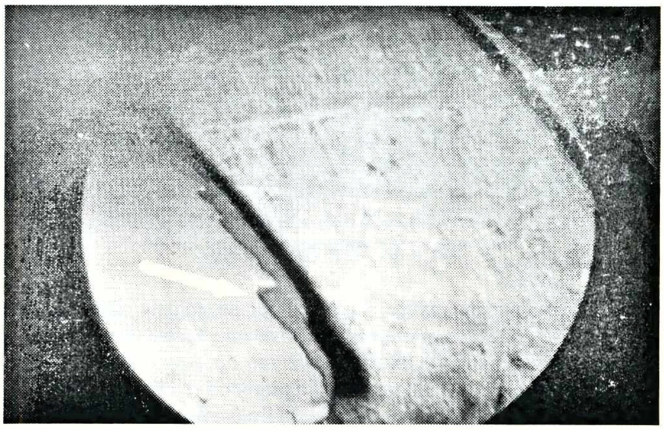

***Fig.11.** The rotor blade of HPT of DR77 engine. Damage (cavities) of protection coating at the blade tip edge*

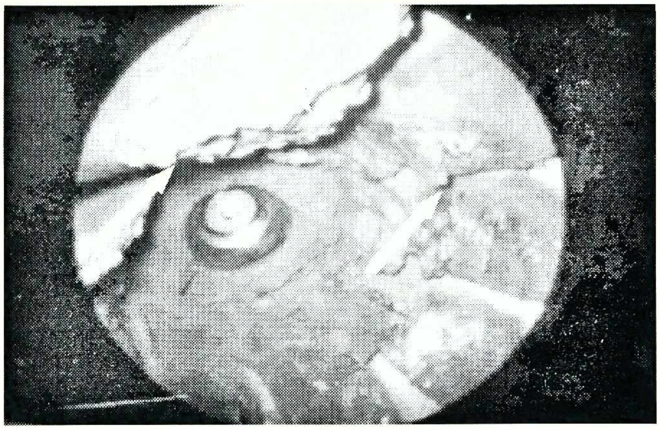

Fig.12. The fire pipe of CC of DE59 engine. Carbon deposit layer on the swirler blades

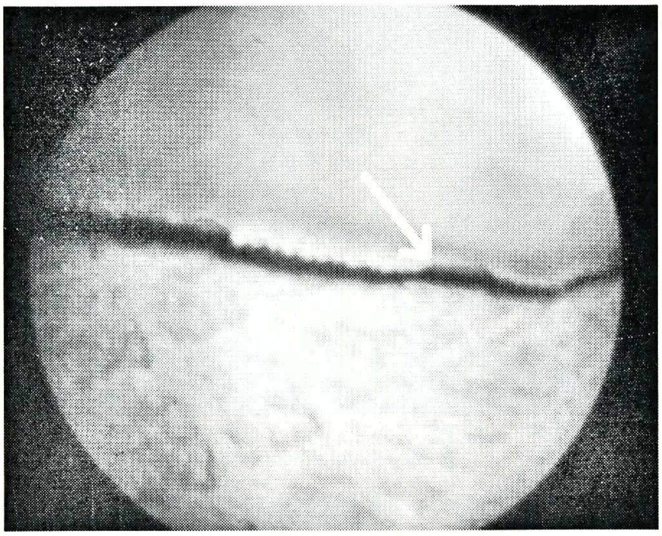

Fig.13. The rotor blade trailing edge of HPT of DR77 engine. Fouled cooling ducts

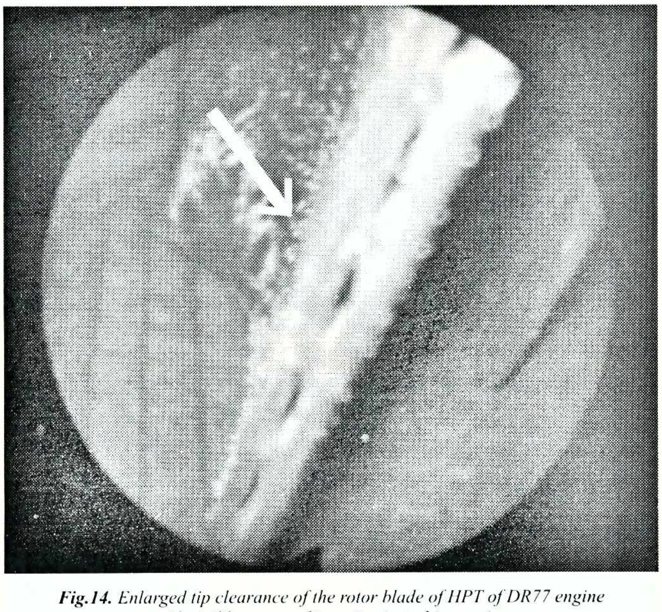

Fig.14. Enlarged tip clearance of the rotor blade of HPT of DR77 engine with visible traces of jamming in turbine casing

The endoscopes were also used for diagnostic assessing the M503 and M520 diesel engines used on the Polish Navy vessels, where disassembling the engine heads was necessary to assess technical state of the over- piston spaces and piston-cylinder system operation [4]. The fiberoscope was especially useful for diagnosing the valve heads and seats.

BIBLIOGRAPHY

1. House E.M.: „Experience with the TF40B engine in the LCAC fleet". International Gas Turbine and Exposition. Cologne, June 1992
2. Rozenberg G.Sz.: „Techniceskaja ekspluatacja sudovych gazoturbinnych ustanovok" (in Russian). Transport. Moskva 1986
3. „Technical specification of DR76, DR77 and DE59 naval gas turbines" (in Polish)
4. „Reports on diagnostic examinations of the gas turbine engines installed on the Polish Navy vessels"(in Polish). Research Proceedings of the Polish Naval Academy, Gdynia 1986 ÷ 1998

Appraised by Adam Charchalis, Prof.,D.Sc.,M.E.

Conference

CTO

III CONFERENCE OF MSC SOFTWARE USERS

The conference was aimed at exchange of the experience gained by MSC software users, presentation of current works and mutual aid in solving current problems emerging during FEM applications.

The conference organized by the Ship Design & Research Centre (CTO) on 5 and 6 November 1998 in Gdańsk, was attended by 62 participants from 21 enterprises and institutions inclusive of a representative of MacNeal-Schwindler Corporation (MSC), Munich, Germany.

Apart from CTO specialist group also representatives of the Warsaw Technical University, Aeronautical Institute, Military Technical Academy, Office of Failure Analysis Associates, Warsaw, and Silesian Technical University, Gliwice, were large in number.

Altogether 26 papers were presented. In addition the MSC gave three thirty-minute presentations.

As far as the conference subject matter is concerned most of the papers (over 70%) dealt with the advanced mechanics problems such as :

- non-linear, static and dynamic analysis of structures
- mechanical contact
- analysis of extrusion and pressing engineering processes
- optimization of structures
- thermal problems.

Most of the papers on linear structural analysis (the remaining abt 30%) were focused on static and dynamic analysis of sophisticated structures inclusive of those made of unconventional materials (composites).

The biggest number of the papers (12, i.e over 50%) came from the aircraft and military equipment industries, the next in order (4, i.e. over 15%) from shipbuilding and ship equipment industries, then from mining industry (3 papers). Other industries were represented by one or two papers.

The Aeronautical Institute and CTO with 4 papers each, Warsaw Technical University and Silesian Technical University with 3 papers each were the most engaged in providing papers.

In comparison with II MSC Conference a considerable progress was now observed in solving more and more ambitious engineering problems.

It could be noticed that MSC software applications were concentrated in the largest R&D centres and most promising industrial branches.