Investigation report

C6/2005L

Helicopter accident in the vicinity of the Vuomaselkä in Sodankylä on 21.9.2005

OH-HAY

Hughes 269C

According to Annex 13 to the Convention on International Civil Aviation, paragraph 3.1, the purpose of aircraft accident and incident investigation is the prevention of accidents. It is not the purpose of aircraft accident investigation or the investigation report to apportion blame or to assign responsibility. This basic rule is also contained in the Investigation of Accidents Act, 3 May 1985 (373/85) and European Union Directive 94/56/EC. Use of the report for reasons other than improvement of safety should be avoided.

SUMMARY

In the vicinity of Vuomaselkä reindeer round-up corral in Sodankylä municipality, about 7 km south-west from Kakslauttanen occurred an accident for a Hughes 259C helicopter, registration sign OH-HAY, owned by a commercial operator, on Wednesday September 21st 2005 at 10.25 Finnish time. The helicopter fell down on the ground from low altitude and was substantially damaged. The pilot and the accompanying observer were slightly injured. Accident Investigation Board Finland set September 26th 2005, through its decision number C6/2005L, an investigation commission to investigate the accident with investigator Ari Huhtala nominated as chairman and investigators Hannu Mäkeläinen and Arja Holopainen as commission members. The investigation commission was assisted by Juhani Mäkelä in the investigation of the accident site.

The crew of the helicopter that had been on a reindeer management flight, noticed that some of the reindeer at the right part of the flock turned around and begun to run away from the incoming opening of the reindeer fence. The helicopter moved to the right to turn back the escaping reindeer towards the opening. The reindeer however did not stop and the pilot descended in front of the reindeer to hover at 5 to 8 meters between sparsely growing high pine trees and simultaneously reduced the ground speed close to zero. During the hover the pilot suddenly felt a strong vibratory motion and the helicopter was rapidly swung to the left. The main rotor blades were struck to a tree on the left rear side of the helicopter and the helicopter fell on the ground simultaneously turning upside down. The pine, cut by the rotor blades, fell on the helicopter. The reindeer caretaker and the pilot left the helicopter through the broken windshield on right hand side. On the ground the reindeer herders, that had driven the reindeer, heard a powerful bang simultaneously when the helicopter main rotor blades hit the tree and the helicopter fell on the ground. The reindeer caretakers immediately started the rescue actions and simultaneously reported the accident to the Emergency Response Center of Lapland.

It was found out in the investigation, that the intake outer valve spring seat of the helicopter engine cylinder number 1 was broken in two pieces. Fractures were also noted to emerge in the spring seats of the three other cylinders. According to the investigations the fracture of the spring seat was caused by an unsuccessful carbon case hardening, with an outcome that the spring seats did not endure a longer usage.

The outer valve spring seat of the helicopter engine intake valve broke in two pieces and caused a rapid loss of the engine power. The helicopter rapidly turned around to the left around its vertical axis and drifted against a tree that was on the left rear side. As a consequence of the main rotor strike, the helicopter fell on the ground.

The accident investigation board recommends, that The European Aviation Safety Agency, EASA, and the Federal Aviation Administration, FAA; should take action so that all intake outer valve spring seats P/N LW10077 of production lot 17328 33-04 of Textron-Lycoming engine HIO-360-D1A shall be replaced by corresponding spring seats of another production lot.

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FOREWORD

In the vicinity of Vuomaselkä reindeer round-up corral in Sodankylä municipality, about 7 km south-west from Kakslauttanen occurred an accident for a Hughes 259C helicopter registration sign OH-HAY, owned by a commercial flying company, on Wednesday September 21st 2005, at 10.25 Finnish time. The helicopter fell down on the ground from low altitude and was substantially damaged. The pilot and the accompanying observer were slightly injured. The accident had many eyewitnesses. They reported the event to the Emergency Response Center of Lapland, which alarmed units of Sodankylä Department of Rescue Services, Saariselkä Rescue Coordination Center and Sodankylä ambulance unit and rescue helicopter Aslak. The accident site was investigated by Sodankylä district police and the police asked assistance from the Infantry Brigade to guard the accident site. The pilot and the passenger were transported to Sodankylä public health-clinic. The investigators arrived to the accident site the same day about 19.30 and commenced the investigation of the site.

Accident Investigation Board Finland set September 26th 2005, through its decision number C6/2005L, an investigation commission to investigate the accident with investigator Ari Huhtala nominated as chairman and investigators Hannu Mäkeläinen and Arja Holopainen as team members. The investigation commission was assisted by Juhani Mäkelä in the investigation of the accident site.

The investigation board made detailed investigations of the helicopter at the accident site September 22nd 2005 and interviewed eyewitnesses. Later the board interviewed different parties more in detail. The technical investigation of the helicopter, including the engine and the fuel system, was done at Rovaniemi Technical Vocational School after which the helicopter was delivered to the owner. The broken intake outer valve spring seats of the engine were sent to the Materials Engineering Laboratory of the University of Oulu, Department of Mechanical Engineering.

The accident investigation commission gave one safety recommendation. The investigation report was sent to the European Aviation Safety Agency and to the Federal Aviation Administration for official comments. Finnish Civil Aviation Administration, the owner of the accident helicopter and the pilot were also given the opportunity to comment on the report. The received comments have been taken in consideration in the investigation report.

The investigation was finished August 9nd 2007.

1 FACTUAL INFORMATION

1.1 Accident flight

1.1.1 Flight preparation and the first flight of the day

It was agreed to fly the reindeer management flights of Lapland Reindeer-owners' Association daily during daylight time when the weather conditions so permitted. The pilot and the reindeer caretaker, acting as observer, started the autumn flights the day before the accident. In the morning of the accident day September 21st 2005 the pilot made the flight preparation and the helicopter daily check according to the check list. Before the flight there was fuel for about 2 hour 40 minute flight in the helicopter. There was no water in the fuel specimen taken by the pilot. The helicopter took off for the first flight of the day at 08.00 and landed for refuelling at the landing site of Vuosnaselkä reindeer fence at 10.15. During the flight the helicopter functioned properly.

1.1.2 Events on the accident flight

After the landing for refuelling at 10.20 the helicopter took off for the second flight of the day. The drive of the reindeer flock had proceeded close to the incoming opening of the reindeer fence. The helicopter flew at an altitude of approximately 120 meters (400 ft) behind the reindeer flock and the reindeer caretakers that were performing the drive on foot and with all-terrain vehicles. Due to a full refuelling the helicopter was heavy during the first half an hour. The helicopter crew noticed that some of the reindeer, at the right hand side of the herd, turned around and started to run away from the incoming opening of the fence. The pilot flew slowly to the right to turn around the fleeing reindeer towards the opening. The reindeer however did not stop after which the pilot descended in front of the reindeer to hover at an altitude of 5 to 8 meters between sparsely growing high pine trees and simultaneously decreased the ground speed close to zero. Close to the ground the pilot, according to his statement, turned the helicopter nose somewhat to the right towards the "loose breaking" reindeer, simultaneously following the behaviour of the reindeer herd. During hovering the pilot checked the engine values that were normal.

During hovering the pilot moved the helicopter slightly to the left. Suddenly he felt a strong vibratory motion and the helicopter rapidly swung to the left. The main rotor blades struck to a tree which was slightly to the rear left side of the helicopter with an outcome that the helicopter fell on the ground turning simultaneously upside down. The pine, cut by the rotor blades, fell on the helicopter. The engine was still running on the ground when the helicopter was upside down. The pilot cut the engine by pulling the choke to lean and turning the magneto to OFF position. The crew left the helicopter through the broken windshield on the right hand side.

On the ground the reindeer caretakers, that had driven the reindeer, heard a powerful bang simultaneously when the helicopter main rotor blades hit the tree and the helicopter fell on the ground. The reindeer caretakers immediately started the rescue actions and simultaneously reported the accident to the Emergency Response Center of Lapland. The pilot notified the Rovaniemi Area Control Service about the accident.

Figure 1. Place of the helicopter impacting on the ground. The helicopter flight direction was from the left to the right. The tree on the left was cut by the main rotor blades.

Figure 2. An overview of the helicopter at the accident site.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Others*
Fatal			
Serious			
Minor/None	2		

1.3 Damage to aircraft

The helicopter was subtantially damaged.

1.4 Other damage

The helicopter main rotor blades cuts a pine tree that was about 16 meters high and 25 cm thick. A small amount of avgas ran on the ground through the ventilation tubes of the fuel tanks. Other fluids did not run into to the surroundings.

1.5 Personnel information

1.5.1 Commander of aircraft:

The pilot had a national license of Estonia, validated by the Flight Safety Authority May 23rd 2005. Age 26 years.

Licenses: Private pilot's licence for aircraft, issued March 26th 1999

Commercial pilot's licence helicopters, issued May 25th 2001

The licence was valid until October 14th 2006

Medical certificate Class 1, valid until October 7th 2005

Ratings: Single piston engine aircraft

Instrument rating, multi engine rating, multi pilot crew rating

Radiotelephone operator's rating in English and Estonian languages

Type rating: HU269 valid until June 30th 2006

Mi8 co-pilot, valid until May 31st 2006

Flight experience	*Last 24 hours*	*Last 30 days*	*Last 90 days*	*Total experience*
All types	10 h 30 min 5 landings	40 h 43 landings	85 h 87 landings	829 h 2532 landings
Type Concerned	10 h 30 min 5 landings	40 h 43 landings	85 h 87 landings	335 h

The pilot started to fly the autumn reindeer management flights the day before. The work session started at 08.00 on the accident day. The day before the working session had started at 08.50 and ended at 15.50.

1.5.2 Observer of aircraft:

The reindeer caretaker acting as the observer was a Chief of District of the Reindeer-owners' Association of Lappi. He had been acting as observer at similar flights during several years. Age 60 years.

1.6 Aircraft information

1.6.1 Helicopter basic data

Helicopter Hughes 269C, fitted with one four-cylinder Lycoming piston engine, is a three-seat light helicopter of metal construction. In this helicopter the pilot sits on the left hand and the observer on the right seat.

Helicopter:

Type:	Hughes 269C
Registration sign:	OH-HAY
Registration number:	1443
Manufacturer:	Hughes Helicopter Co, USA
Serial number:	1270662
Year of manufacture:	1977
Certificate of Airworthiness:	valid until September 30th 2006
Maximum take-off mass:	930 kg (2050 lbs)
Total flight time September 21st 2005:	8234 h 55 min

Engine:

Type:	HIO-360-D1A
Serial number:	L-25788-51A
Manufacturer:	Textron-Lycoming, USA
Total run time:	116 h 00 min
Fuel:	Avgas, 100LL

1.6.2 Airworthiness

The Helicopter certificate of registration No 1443 was issued August 21st 2002. The certificate of Airworthiness was issued September 14th 2006 and was valid until September 30th 2006.

1.6.3 Weight and balance

The helicopter maximum take-off mass is 930 kg. The helicopter basic mass inclusive equipment is 543.4 kg. The mass of the pilot and the passenger was about 160 kg. At take-off the helicopter had fuel about 134 kg (185 l). At the instant of the event there was about 123 kg of fuel left. The take-off mass was altogether approximately 837 kg. The center of gravity was within allowable bounds during the entire flight.

1.7 Meteorological information

The pilot told that there was a weak westerly wind at the instant of the event. The day was partly cloudy and the visibility was good. In Vuotso village is situated a SYNOP station of the Finnish Meteorological Institution Northern-Finland regional services. The station had registered at 09.00 that the wind was calm and at 11.00 the wind was 270 degrees with 4 knots. Weather data from Saariselkä SYNOP station were not available for the instant of the event. The conditions for the flight were excellent.

Weather at Ivalo airport:

At 10.20: wind 250 degrees 3 knots, variation of wind direction 220-300 degrees and speed 2-6 knots, visibility 50 km, scattered clouds at 10000 ft (3040 m) partly cloudy at 20000 ft (6090 m), temperature +2 °C, dew point 0 °C and ambient pressure (QNH) 1001,3 hectopascal (hPa).

At 10.50: wind 250 degrees 3 knots, variation of wind direction 210-280 degrees and speed 1-5 knots, visibility 50 km, scattered clouds at 10000 ft (3040 m) partly cloudy at 20000 ft (6090 m), temperature +3 °C, dew point 0 °C and QNH 1001.3 hPa.

1.8 Aids to navigation

Navigation aids had no impact on the event.

1.9 Communications

The pilot did not have time to report the accident with the radio telephone. After the accident the pilot called the Rovaniemi Area Control Service with a cell phone and made a report about an accident.

1.10 Aerodrome information

The take-off place is situated in the village of Vuotso. The place did not have an effect on the course of matters.

1.11 Flight recorders

There were no flight recorders in the helicopter.

1.12 Wreckage and impact information

1.12.1 Accident site

The accident site is situated within the municipality of Sodankylä on the North-East slope of an arctic hill west of Vuomaselkä round-up corral. The WGS84 coordinates of the place are 68°17,472 N and 027°13,817 E and elevation from sea level is 314 meters. In the terrain of the accident site there had been thinning cuts and sparsely growing pines had been left as seed trees. The height of the trees was about 15 to 20 meters.

The helicopter main rotor blades had hit a pine tree with a diameter of about 25 cm. The first hit of the blade tip was at 3.6 meter's height in the tree and the next blade strike had cut the tree at 3.1 meter's height from the ground. The blade tip, that had hit the tree, had flown about 250 meters from the wreckage. The helicopter had fallen down from about 1 meter's height and turned inverted resting on the cockpit. The tree, cut by the rotor, had fallen on the helicopter. The helicopter had not hit other trees during the flight.

1.12.2 Inspection of aircraft remains

The helicopter cockpit structure was damaged. All windows were broken. The doors were in place but deformed. The safety belts were intact and functioning. The instrument panel was in one piece, but it was partly ripped off and turned away from its place. Only the left hand side controls were connected. The controls were intact and functioning.

The support structure for the main rotor hub and mast and the mast were cut off. The main rotor blades were in place in the hub, but they were bent in several crooks into one bundle and fractured in the tips. A diagonal supporting the belt drive was cut off. The engine drive belts were in place and shape. The main drive axle was intact. Both supports for the tail boom were damaged and the tail boom was distorted from the root fitting. In the ground impact one of the tail rotor blades was broken and the elevator was damaged. The tip of the left landing gear tube was broken at the forward support and its both shock absorbers were cut of at their upper brackets.

The engine mounts were intact. The right hand side fuel tank was pressed in at the end and there was a punched hole. The left hand side fuel tank was intact. The upper belt drive wheel had chafed a buckle on the inside end of the tank. Fuel had leaked on the ground through ventilation tubes. Wooden plugs had been put into the tube ends after the accident. There was plenty of fuel in both tanks. The majority of the helicopter parts were in the vicinity of the impact place.

1.13 Medical and pathological information

Both crew members had a medical inspection at Sodankylä health care center. The pilot was not injured. The observers got scratches in his face and bruise in his eye brow. There were also bruises in his right arm and the muscles felt tender. The results of the breath analyzer tests for alcohol made for the pilot and the accompanying observer had a value of 0.00 ‰.

1.14 Fire

No fire.

1.15 Survival aspects

The pilot and observer left the helicopter by themselves. The reindeer caretakers, working in the vicinity of the accident site, helped the crew simultaneously when one of the reindeer caretakers reported the accident to the Emergency Response Center of Lapland. The center commenced the rescue activities by alarming units of Sodankylä Department of Rescue Services, Saariselkä Rescue Coordination Center and Sodankylä ambulance unit, as well as rescue helicopter Aslak to the site. About 45 minutes after the event, at 11.10, the units of the Saariselkä Rescue Coordination Center arrived to the site. At 11.27, rescue helicopter Aslak and at 11.30, Sodankylä ambulance unit arrived to the site. Slightly later arrived also units from Sodankylä Department of Rescue Services and a patrol from Sodankylä district police to the site. The police asked assistance from the Infantry Brigade in Sodankylä to guard the accident site and the wreckage.

The crew had four point safety harnesses during the entire flight. There was no Emergency Locator Transmitter (ELT) in the helicopter.

1.16 Test and research

The helicopter was fitted with an engine overhauled by the manufacturer June 2nd 2005. At the time of accident, the engine running time since overhaul was 116 hours. After the engine overhaul only a few pilots had flown the helicopter and it had not been used for training. There were no reports about possible engine over speeding in connection with engine start or during flight.

1.16.1 Technical inspection

The main rotor blades were inspected visually. The blade skin sheets were torn off from the bonded joints and the blades were strongly bent into crooks and fractured in the tips. The blade fitting bolts were intact and no bending was noticed in them. The fuselage frame structure was intact except two small deformations. In the inspection of fuel tanks no kinds of contaminations were noticed. The filters of the fuel system were checked and they were clean and there was no water or contamination in the water separation cup. The engine suction air filter was clean.

1.16.2 Detailed engine investigation

In the external inspection it was noticed that the shroud tube of engine cylinder number 1 intake valve pushrod was bent. A closer inspection showed, that the outer valve spring seat of the intake (P/N LW10077, Lot 17328 33-04) was broken apart and the valve had freely moved into the cylinder. Within the cylinder the valve was broken in several pieces. The valve shaft was broken above the valve plate and pushed by the piston the valve shaft had pushed the valve guide out of its place. The majority of the valve seat pieces were in the intake channel and a portion in the damaged cylinder.

Figure 3. The bent shroud tube of cylinder number 1 intake valve pushrod.

Figure 4. The intake valve of cylinder number 1 had moved into the cylinder.

Figure 5. The broken outer valve spring seat and valve retaining keys of cylinder number 1 intake valve.

It was further noticed, that also the intake outer valve spring seat of cylinder number 4 was almost broken apart. All cylinders were removed and their intake valve mechanisms were dismounted. Then it was noticed that there were emerging fractures also in the lower edges of the locking cones of cylinders number 2 and 3 outer spring seats. All damaged spring seats were from the same production lot.

Figure 6. Intake outer valve spring seat of cylinder number 4.

Figure 7. Intake outer valve spring seat of cylinder number 2.

Figure 8. Intake outer valve spring seat of cylinder number 3.

All outer valve spring seats of the engine intake valves were sent to the Materials technology laboratory of Oulu University Faculty of Mechanical Engineering for detailed investigations. For reference tests corresponding new spring seats and spring seats from an engine with a run time completed for an overhaul period were ordered from the representative of the engine manufacturer. In the tests, made by the university, it was concluded that:

> *”Small differences in macrohardness values and differences in the inclusion structure can not explain the failure of the valve spring seats. Neither were any marks of fatigue visible in the scanning electron microscope examination but the overloading is the reason for the failure. The most evident reason for the cracking of the valve spring seats is improper carburization (thin layer and low hardness) in which even soft ferrite grains are present in the hardened layer. This also means that compressive residual stresses were lower than desired.”*

The hardness profiles of the case hardened layer of the intake outer valve spring seats from the cylinders 1–4 are presented by black circles and continuous lines. Reference spring seats (KLI, KLI-0, WITHOUT CODE, SMP) are presented by white circles and dashed lines. Hardness profiles should pass trough the area coloured grey. Grey area presents the design specification for hardness in given distance from the surface (hardness 87–91 HR15N at 0.008”–0.014”).

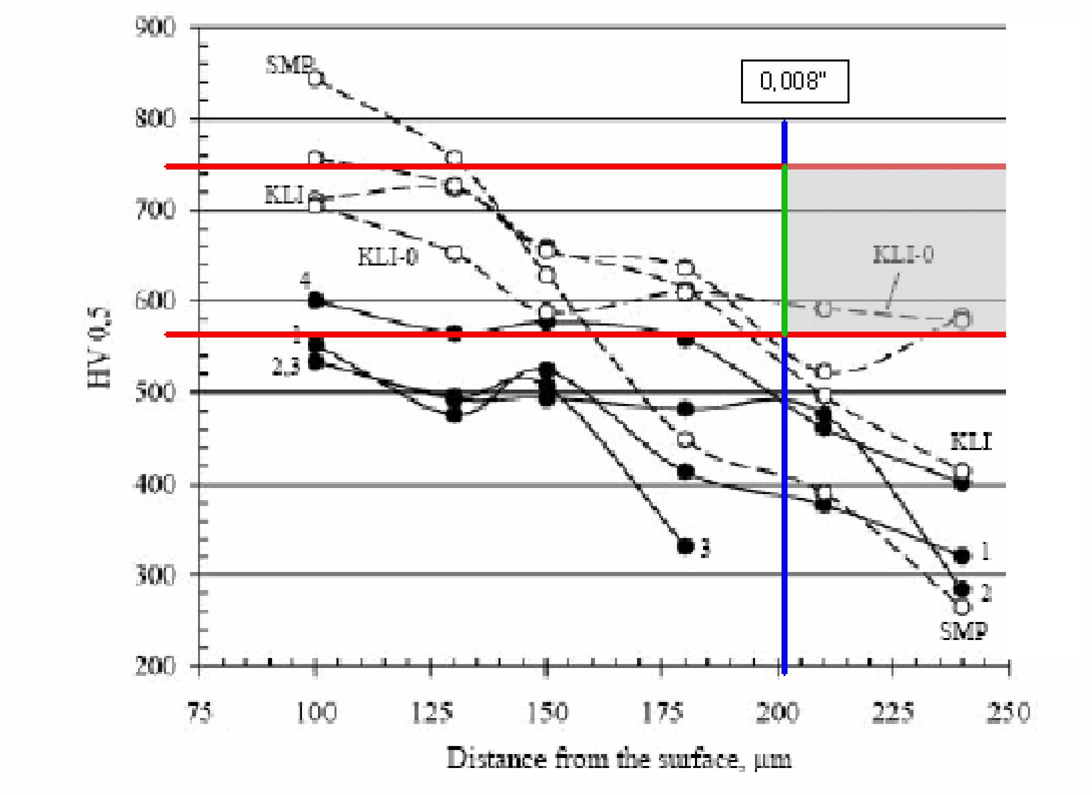

Figure 9. Hardness profiles of the case hardened layer of the intake outer valve spring seats.

1.16.3 Other engine investigations

The spark plugs were removed and they were noted to be in good condition. Compression checks were performed for intact cylinders. The measuring results were within the service specifications. The magneto timings were correct and the magneto structures were intact. In the same connection the engine was inspected according to Lycoming Mandatory Service Bulletin No 369J, Nov. 22. 2004 to reveal possible engine over speeding. Based on the inspection no exceeding of the limit values was noticed. There was no contamination in the engine lubrication system oil or oil filter.

1.17 Organizational and management information

The aircraft operator had an Air Operator Certificate, issued by Flight Safety Authority, valid until January 31st 2008. The company had a training program for reindeer management flights. The pilot had been given a theoretical and flight training according to the program. He had been approved to work independently since May 1st 2005. The accountable manager of the company had given the pilot recurrent training for reindeer management flights at the area of reindeer herder's association of Lappi during June-July in the same year. During the flights collecting and driving reindeer was trained in different conditions. The accountable manager was in person monitoring the now commenced reindeer management flights. According to the investigators, the pilot's training and familiarization for the flight task had been thorough and sufficient.

The helicopter annual checks, regular maintenance and engine checks were made by an aviation maintenance company approved for maintenance.

1.18 Additional information

In November 2006 the final draft of the investigation report was dispatched to the European Aviation Safety Agency (EASA) and the Finnish Civil Aviation Authority as well as to the other parties concerned for comments. Due to the investigation report EASA dispatched a safety recommendation to the Federal Aviation Administration (FAA) and to the manufacturer of the engine, Textron-Lycoming, for comments. EASA requested, after a proposal from the FAA, the accident investigation commission to send the samples of the damaged intake outer valve spring seats to Textron-Lycoming for investigations of their own. The parts were supplied to the engine manufacturer in the beginning of February 2007. When inquired Textron-Lycoming announced that they have informed FAA with the results in order for FAA to take action and to contact Accident Investigation Board Finland. The FAA has not given a statement over the matter.

2 ANALYSIS

2.1 General

After the engine overhaul the helicopter had been flown 116 hours by only a few pilots. There have been no reports about possible engine over speeding in connection with engine start or during the flight. After the engine overhaul the helicopter had not been used for training, where autorotation landings would have been practised. The maximum allowed engine rotational speed may be exceeded in autorotation exercises.

After the accident the pilot reported it according to Finnish Aviation Regulation GEN M1-4. In his report the pilot ascertained that just before the rotor blades hit the tree the helicopter nose rapidly swung to the left. In the hearing he specified the sequence of events. The investigators' view is that the rapid swing to the left of the helicopter's nose resulted from an abrupt loss of engine power. If the helicopter rotor blades had first hit the tree or if the tail rotor had lost its power the nose should have swung to the right, because in this helicopter type the main rotor blades rotate counter clockwise.

In the technical investigations it was concluded that the suction valve outer spring seat of cylinder number one in the helicopter engine had broken apart. As a consequence of this, the engine lost its power and the helicopter descended rapidly simultaneously gliding in laterally to the left. Then the main rotor blades hit a nearby tree. In this helicopter type a rapid loss of engine power instantly causes a rapid rotation and a lateral motion to the left.

2.2 Technical investigation

Besides the engine cylinder number 1 broken intake outer valve spring seat there were fractures in intake valve spring seats of three other cylinders. According to the investigations of Oulu University the most probable cause for the fracture of the intake outer valve spring seats is a weak carbon case hardening (thin layer and low hardness) with a ferrite web formed in the surface in the carbon case hardening. At the same time the entire advantage of the carbon case hardening, a compression stress in the surface, is lost. Cylinder number 4 spring seat and thickness barely fulfil the minimum requirements of the engine manufacturer. The hardness of the carbon case hardening of cylinder 1, 2 and 3 on the contrary did not fulfil the minimum requirement. Moreover the thickness of the hardened layer was less than claimed by the requirements. Consequently the hardening had failed and the spring seats did not endure normal usage a longer time.

2.3 Previous investigations

The investigators know that two engine failures have previously occurred for helicopters of the same type. The first event occurred March 3rd 2001 in the village of Petäjäkoski when cylinder number 1 intake outer valve spring seat of a helicopter broke enroute and the helicopter made a successful landing. The runtime of the overhauled engine was

142 hours. The engine manufacturer reported that: *”There have been other reports of broken spring seats, but not to a point of concern considering the number of engines utilizing this part”*. The factory’s report could be interpreted so that the event in question is rare and has not warranted further action.

The second event occurred in Denmark in June 2005. Only 29 hours after overhaul the outer valve spring seat of the utilized engine intake valve broke in the middle of the flight and the helicopter made a forced landing. This engine had a broken spring seat from the same production lot as in the case now being investigated. The engine parts were investigated at the manufacturer. The thickness of the carbon case hardening was 0,008 inches, which is the same as the manufacturer’s minimum requirement. The hardness of the hardening was noted to clearly fulfil the manufacturer’s requirements. The manufacturer announced as its standpoint that a possible cause would be engine over speeding.

Some engines used in aircrafts have intake outer valve spring seats with the same production lot number. The maximum rotational speed of these engines is several hundreds lower than the maximum rotational speed of the engine studied. The investigators have no information that there would have arisen problems in these engine parts in aircraft engine usage.

2.4 Crew actions

The pilot had prepared the flight carefully. After refuelling the helicopter took off for the second flight of the day about 100 kg below the maximum take off weight. Due to the full fuel-load, the helicopter is ”heavy” in weight during the first one and a half hour. Then the helicopter must be kept in motion and handled with special care.

The pilot told that in order to stop the scattering reindeer herd, the observer asked him to descend in front of the reindeer. The pilot assessed the place and conditions suitable and descended to a few meters’ hovering altitude in front of the reindeer between sparsely growing trees. He was aware that the place was narrow and according to him the engine power was almost entirely in use. In post assessment the choice of the opening in the wood was not the best possible. The opening between the seed trees was so small in area that continuing the aerial work flight with the heavy helicopter would have been awkward and time consuming. However, this event did not have an impact on the arising of the accident.

2.5 Rescue activities

The Emergency Response Center of Lapland did not alarm the rescue units of Inari Department of Rescue Services or units of Ivalo ambulance, although the distance from Ivalo to the accident site would have been about 50 km. The distance from Sodankylä, from where the majority of the units were sent to the site, measured over 110 km.

3 CONCLUSIONS

3.1 Findings

1. The pilot had valid licenses and ratings.

2. The Helicopter's Certificate of Registration and Certificate of Airworthiness were valid.

3. The flight operator had a valid Air Operator Certificate and an approved maintenance company was responsible for aircraft maintenance.

4. Before beginning the reindeer management flights the pilot was acquainted to reindeer management flights.

5. The helicopter was fuelled slightly earlier and it was about 100 kg below maximum take-off mass.

6. In connection with the task the helicopter flew in close vicinity of the ground.

7. The intake outer valve spring seat of the helicopter's engine cylinder number one broke apart and the engine immediately lost its power.

8. There were fractures also in intake outer valve spring seats of engine cylinders numbers 2, 3 and 4.

9. All damaged outer spring seats of intake valves were from the same production lot.

10. Due to the loss of engine power the helicopter drifted against a pine-tree at the rear left side of the helicopter. The main rotor blades hit the tree and the helicopter impacted on the ground.

11. The helicopter fell upside down and was badly damaged.

12. The people on board the helicopter were slightly injured.

13. The reindeer herders commenced the rescue activities.

14. The Emergency Response Center of Lapland did not alarm the units of Inari Department of Rescue Services and ambulance, which were considerably closer.

3.2 Probable cause

The outer valve spring seat of the helicopter engine cylinder number 1 intake valve broke apart and caused a rapid loss of the engine power. The helicopter rapidly rotated to the left around its vertical axis and drifted against a tree on the rear left side. As a consequence of the main rotor strike the helicopter impacted on the ground.

4 RECOMMENDATIONS

Besides the engine fault in question a case is known with an engine fault in the same type of helicopter, occurred in Denmark in June 2005. In both cases the intake outer valve spring seats, P/N LW10077, and production lot numbers, Lot 17328 33-04, are the same. In the case now being investigated the intake outer valve spring seats had been fractured in all cylinders.

1. The European Aviation Safety Agency, EASA, and the Federal Aviation Administration, FAA; should take action so that all intake outer valve spring seats P/N LW10077 of production lot 17328 33-04 of Textron-Lycoming engine HIO-360-D1A shall be replaced by corresponding spring seats of another production lot.

Helsinki 9 August 2007

Ari Huhtala

Hannu Mäkeläinen

Arja Holopainen

LIST OF SOURCES

The following material is stored at the Accident Investigation Board Finland.

1. The decision of Accident Investigation Board Finland to perform the investigation.
2. Investigation board's diary.
3. Requests of comments and received answers.
4. Minutes of hearing
5. Copy of aircraft Certification of Registry, Permit to Fly, the last form of Airworthiness review, weighing protocol, insurance certificate and flight manual with appendices and approval documents.
6. Weather information at the time of the event
7. Alarm and accident reports
8. Statement of Oulu University Faculty of Mechanical Engineering
9. Photographs (2 CD discs) and map drawings over the accident site

ILMAILUHALLINTO
LUFTFARTSFÖRVALTNINGEN
FINNISH CIVIL AVIATION AUTHORITY

Päivämäärä | Datum | Date 10.1.2007

Dnro 11/01/05

STATEMENT
(Translation of the original document in Finnish)

Accident Investigation Board, Finland
Sörnäisten rantatie 33 C
00580 HELSINKI

Viite / Ref: Your request for comments dated 15 November 2006

Asia / Ärende / Subject: **FINNISH CIVIL AVIATION AUTHORITY'S STATEMENT ON THE FINAL DRAFT OF INVESTIGATION REPORT C6/2005 L CONCERNING A HELICOPTER ACCIDENT IN VUOMASELKÄ ON 21 SEPTEMBER 2005**

The Finnish Civil Aviation Authority has no comments on the safety recommendation issued in the investigation report.

Any necessary actions based on the safety recommendation will be decided on separately.

Director General

(signature)
Kim Salonen

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Finnish to English translation of the Finnish-language report 02/24/06 (Order No: C6/2005L).

NOTE: In order to avoid any missinterpretation the Finnish report should preferably be referred.

10 March 2006

Contact person: Ari Huhtala

Failure of the intake valve train of the helicopter engine

The engine HIO-360-D1A (S/N L-25328-51A) under investigation is a piston aircraft engine remanufactured by Textron-Lycoming on 8 February 2005 and assembled into Hughes 269C helicopter (registration mark OH-HAY) on 2 June 2005. Prior to failure, the engine had 116 hours of service since a major overhaul was undertaken. The earlier service time of the engine is not informed.

Damaged and, for comparison, undamaged components (**Fig. 1**) of intake valve train of Lycoming engine were undertaken for failure investigation. The aim was to find out the fracture mechanism of the failed spring seats and to identify possible fatigue mechanism and also measure the Vickers hardnesses of the spring seats and valve retaining keys. All failed spring seats had a designation LW 10077 17328 33-04. New spring seats delivered by the manufacturer had designations LW 10077SMP, LW 10077 KLI and LW 10077 KLI-0. One spring seat did not have any designation (WITHOUT CODE) and it had been in service since the time of one main overhaul.

Failed components were studied by visual examination and pieces cut from components and test samples (**Fig. 2**) were examined by using an optical microscope and a scanning electron microscope (SEM). Macro- and microhardness measurements were carried out at the cross-sections of the test specimens using the Vickers method (HV0.5 and HV0.1).

Results and observations

The measured hardness values for the failed the spring seats and for the reference spring seats are on average 147-168 HV5 (cross-section, fig. 2c) and 150-160 HV5, respectively. The measured hardness values for the valve retaining keys are on average 181-192 HV5 (cross-section, fig. 2b) and 199-205 HV5 (cross-section, fig. 2a). For the reference retaining keys the measured hardness values are somewhat lower, on average 175-177 HV5 (cross-section, fig. 2b) (**Table 1**).

According to the microstructure studies, the spring seats have been case hardened (after machining). The base material itself is so-called a free cutting steel containing copious manganese sulphides (MnS), which enable fast machining using automatic turning lathe. The case hardened layer is clearly visible as the dark area on the micrographs taken from the cross-section surface as seen in fig.2c of spring seats (**Figs. 3-6**). The average thickness of the carburization layer (dark areas in figs. 3-6) in the failed spring seats is 0.2-0.3 mm and in the reference spring seats 0.2-3.5 mm. The measured

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hardness values in the case hardened layer (measuring site in fig. 2) near the surface (circa 100 µm from surface) in the failed spring seats are 553-601 HV 0.5 and in the reference spring seats 665-844 HV 0.5. The case hardened depth, corresponding to the distance from the surface at which the hardness is equal to 550 HV (SFS-EN ISO 2639), is circa 0.16 mm in the reference spring seats. In the failed spring seats, the hardness profile is mainly below the threshold value of 550 HV. (**Table 2, Figs. 7,8**).

According to the digital image analysis (**Figs. 9**,**10**, **Table 3**) the phase fraction of MnS inclusions in the failed spring seats is 1.4-1.8 % and in the reference spring seats 1.1-2.0 %, whereas the number of inclusions is 447-639 kpl/mm^2 and 153-204 kpl/mm^2, and the average area is 24-32 µm^2 and 98-119 µm^2, respectively.

The spring seat core has a banded microstructure, where fine grained ferrite-pearlite bands (or ferrite-bainite bands) and coarse grained ferrite bands alternate. In the failed spring seats the ferrite grain size in ferrite band is on average larger than in the reference spring seat (**Figs. 11,12**). In addition, in failed spring seats a ferrite network in many places extends to the surface of the case hardened layer at the location of the ferrite band (**Fig. 13**). Similar ferrite network is also visible in the microstructure observed on the surface of the spring seat 2 at the crack site (**Figs. 2f,14**). Instead to that, in the reference spring seats the corresponding network was not found.

Fracture surfaces were studied using the opposite surfaces of the crack in the spring seat of the cylinder 4 (**Fig. 2g,f**). The fracture surface inspected visually had an oriented macrostructure corresponding to the banded microstructure mentioned earlier. According to the SEM studies, the fracture surface in the case hardened layer was mostly intergranular mode (**Figs. 16,18**). In the core, the fracture surface had both ductile and brittle features and it contained numerous MnS inclusions (**Fig. 17**). Any marks of fatigue was not observed.

Conclusions

The hardness measurements conducted on the spring seats and the retaining keys do not show significant differences. Higher hardness values of the retaining keys used in the failed spring seats refer to deformation while in service. According to the metallographic studies the failed spring seats and the reference spring seats have differences both in the inclusion structure as well as in the microstructures of the core and the case. The hardness profile of the failed spring seats is mainly below the case hardening threshold hardness of 550 HV, which is due to the ferrite network in the case hardened layer (fig. 13). The ferrite network is remained in the ferrite band especially during the carburization stage. Because the diffusion of carbon occurs mainly along the grain boundaries, there is not enough time for perfect carburization in the coarse grained ferrite bands (Figs. 13,15). Instead, in a ferrite-pearlite band, carburization occurs completely and the carburization zone is deeper due to a small grain size and a higher carbon content of pearlite. In reference spring seats, the ferrite nework in ferrite bands was not observed.

Small differences in macrohardness values and differences in the inclusion structure can not explain the failure of the valve spring seats. Neither were any marks of fatigue visible in the scanning electron microscope examination but the overloading is the reason for the failure. The most evident reason for the cracking of the valve spring seats is improper carburization (thin layer and low hardness) in which even soft ferrite grains are present in the hardened layer. This also means that compressive residual stresses were lower than desired.

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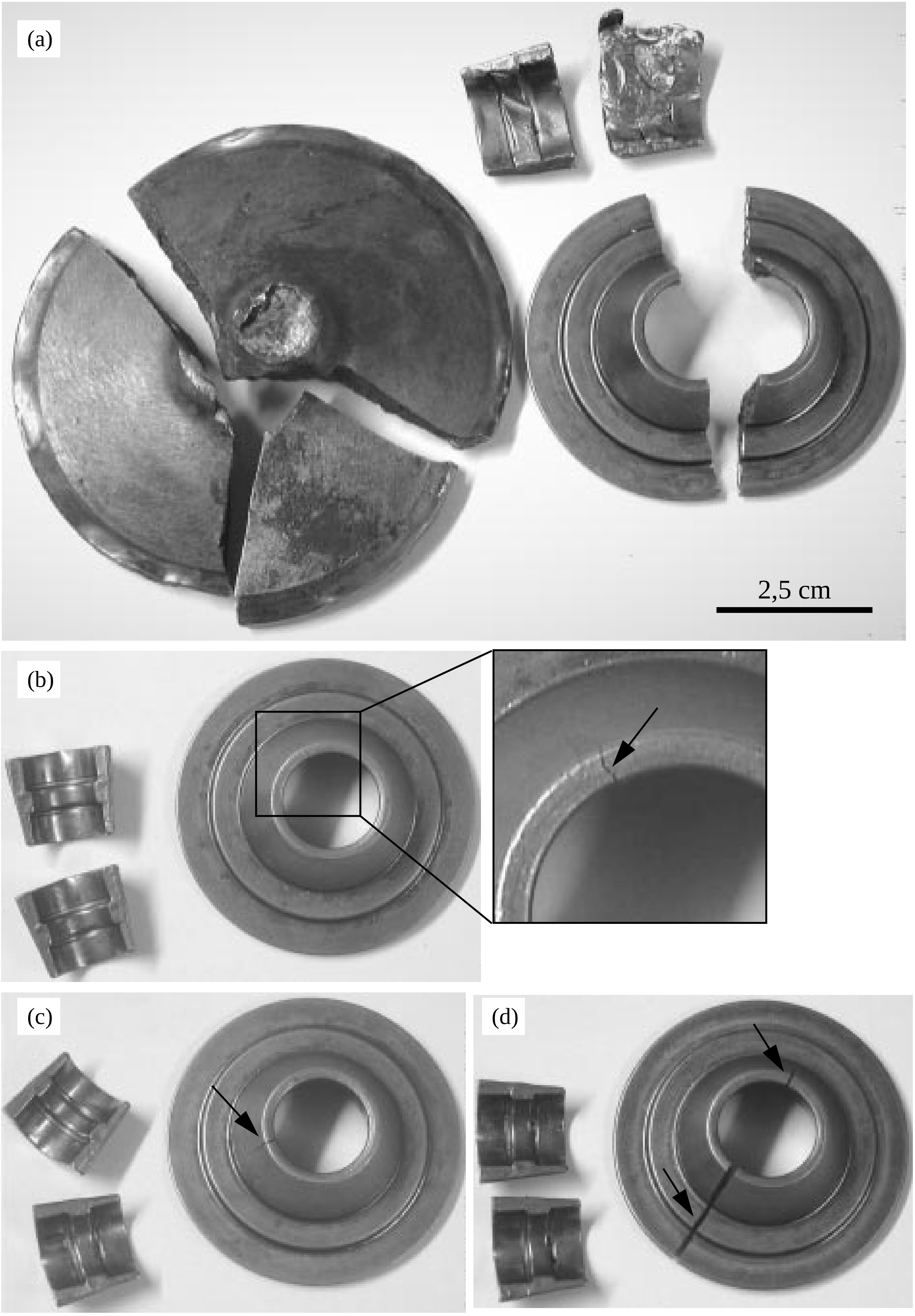


Fig 1. Damaged intake valve train components. (a) Splitted intake valve, spring seat and deformed valve retaining keys of cylinder 1, (b,c,d) Cracks (arrows in Figs.) in the spring seats of cylinders 2, 3 and 4 (respectively) and the valve retaining keys of the same cylinders.

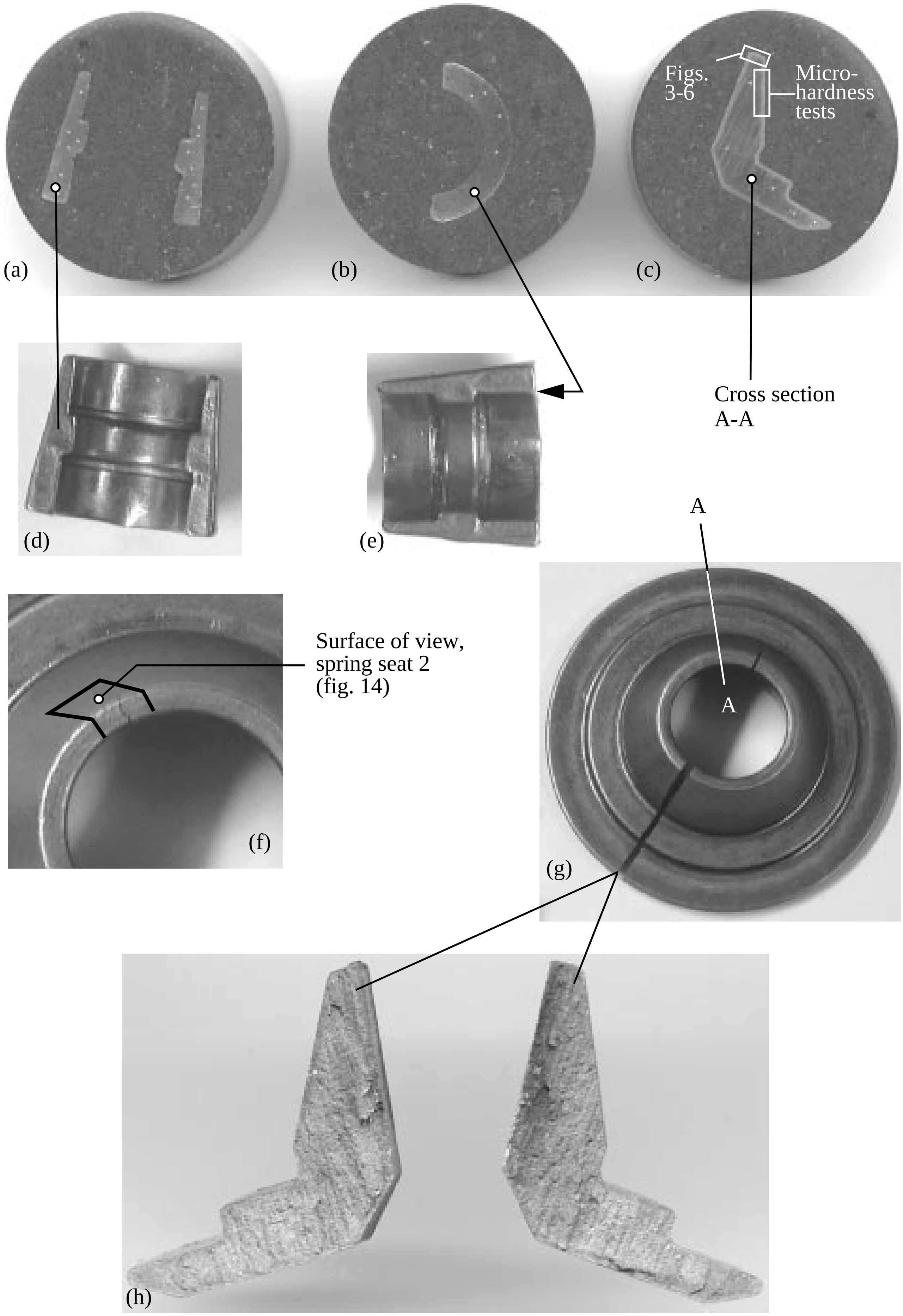
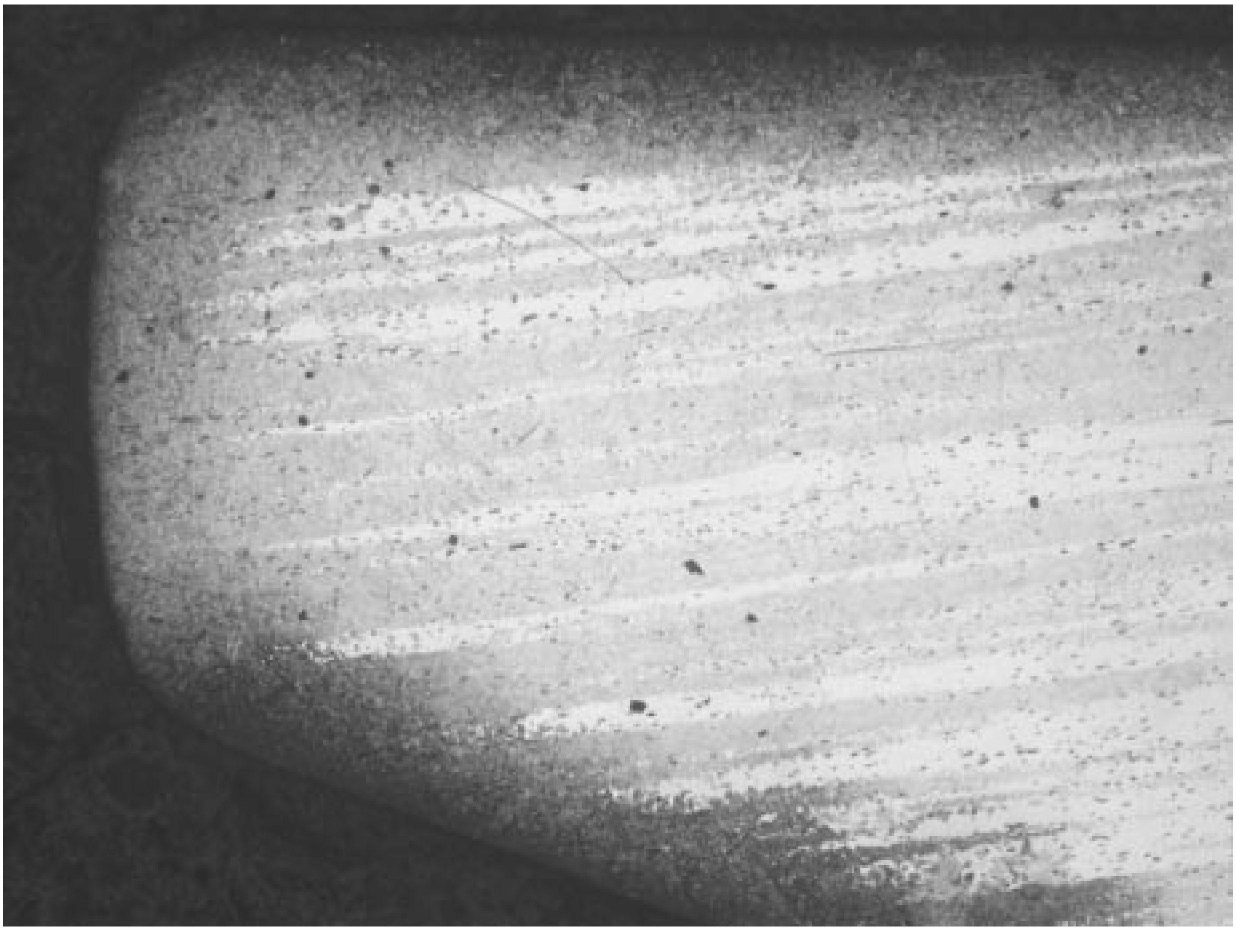


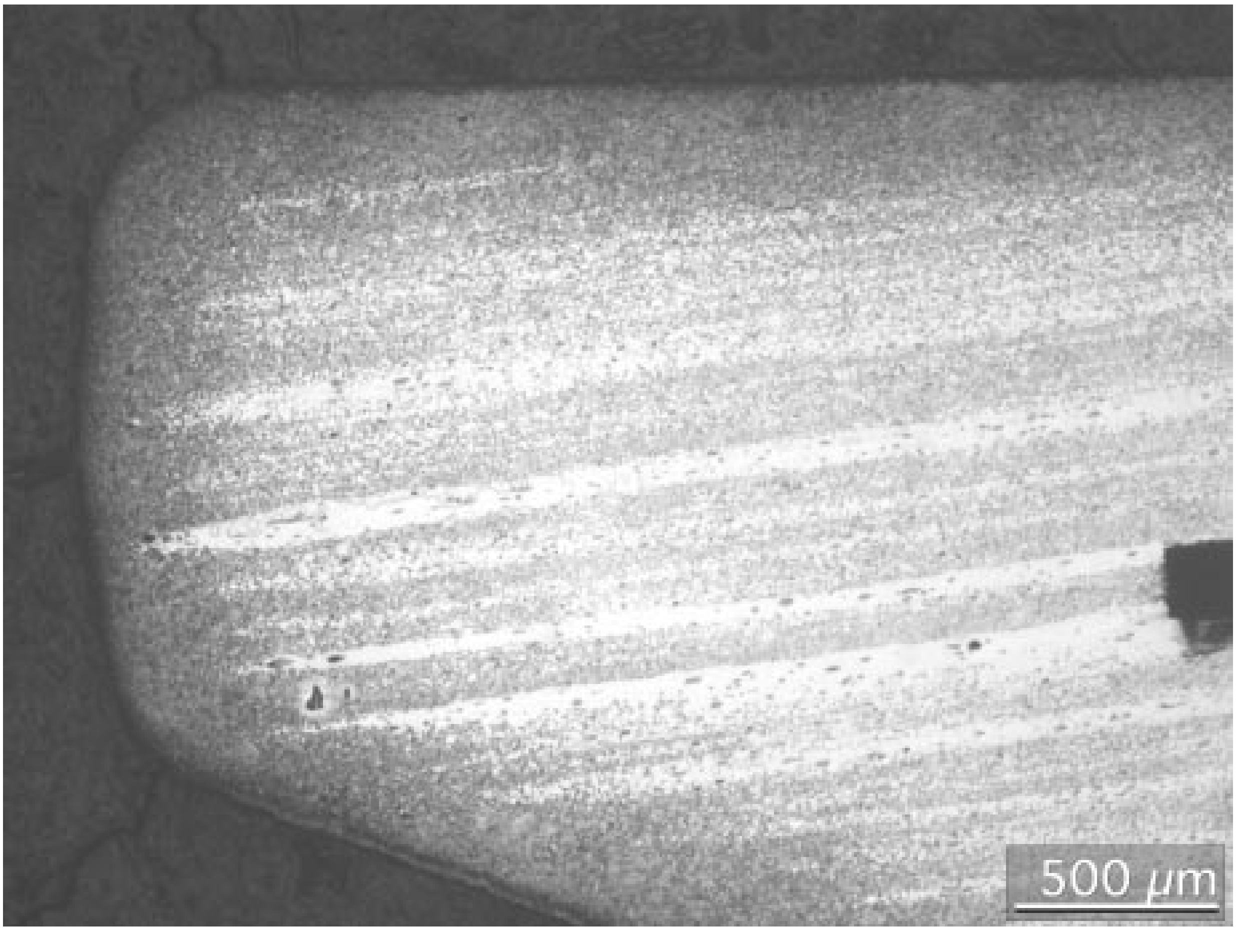
Fig 2. Specimens for testing.

Table 1. Measured and average Vickers hardness (HV5) of spring seats and valve retaining keys.

Specimen	HV5 Meas. 1	HV5 Meas. 2	HV5 Meas. 3	HV5 Average
Spring seat (fig. 2c), Cylinder 1	154	143	145	**147**
Spring seat (fig. 2c), Cylinder 2	148	157	154	**153**
Spring seat (fig. 2c), Cylinder 3	148	148	161	**152**
Spring seat (fig. 2c), Cylinder 4	175	175	154	**168**
Spring seat (fig. 2c), LW 10077SMP	161	145	145	**150**
Spring seat (fig. 2c), LW 10077 KLI	161	148	168	**159**
Spring seat (fig. 2c), LW 10077 KLI-0	154	154	165	**158**
Spring seat (fig. 2c), WITHOUT CODE	157	154	168	**160**
Valve retaining key (fig. 2b), Cylinder 1	192	192	193	**192**
Valve retaining key (fig. 2b), Cylinder 2	183	183	192	**186**
Valve retaining key (fig. 2b), Cylinder 3	186	175	183	**181**
Valve retaining key (fig. 2b), Cylinder 4	182	197	184	**188**
Valve retaining key (fig. 2a), Cylinder 2	201	204	192	**199**
Valve retaining key (fig. 2a), Cylinder 3	201	210	204	**205**
Valve retaining key (fig. 2a), Cylinder 4	210	197	204	**204**
Reference valve retaining key 1 (fig. 2b)	180	180	172	**177**
Reference valve retaining key 2 (fig. 2b)	172	175	180	**176**
Reference valve retaining key 3 (fig. 2b)	180	172	172	**175**

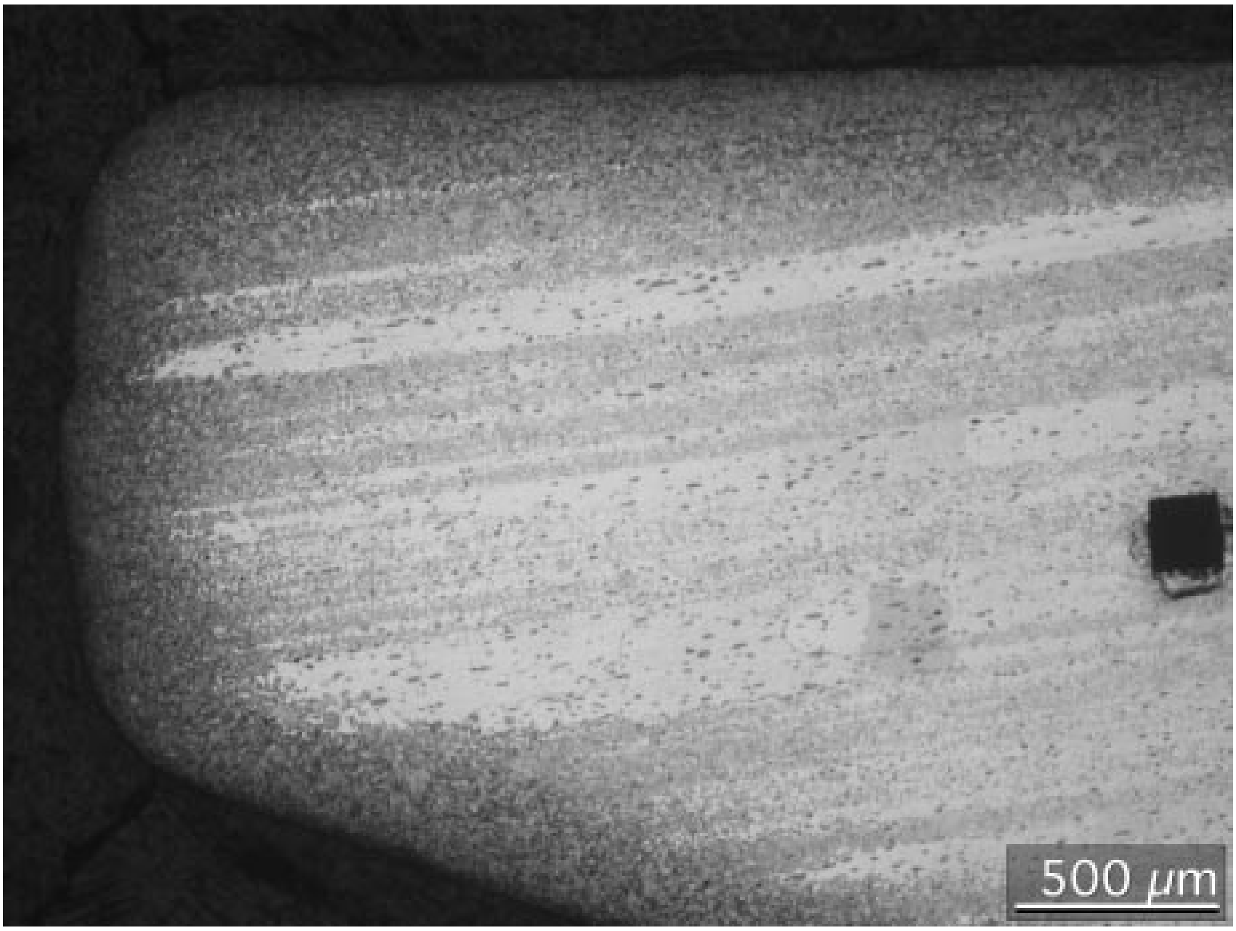


(a)

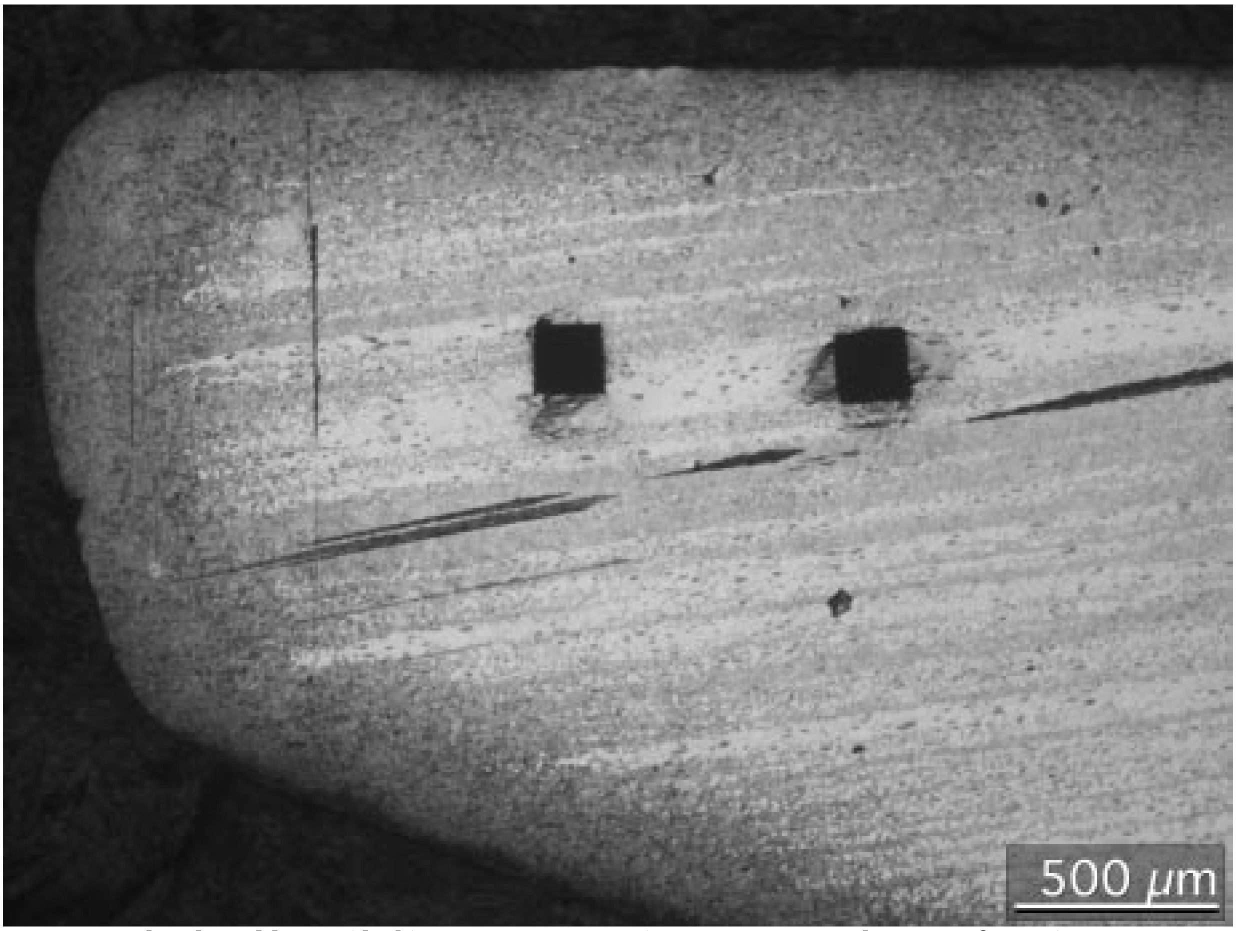


(b)

Fig 3. Case hardened layer (dark) on a spring seat (cross section is shown in fig. 2c), (a) Cylinder 1, (b) Cylinder 2. Optical microscope.

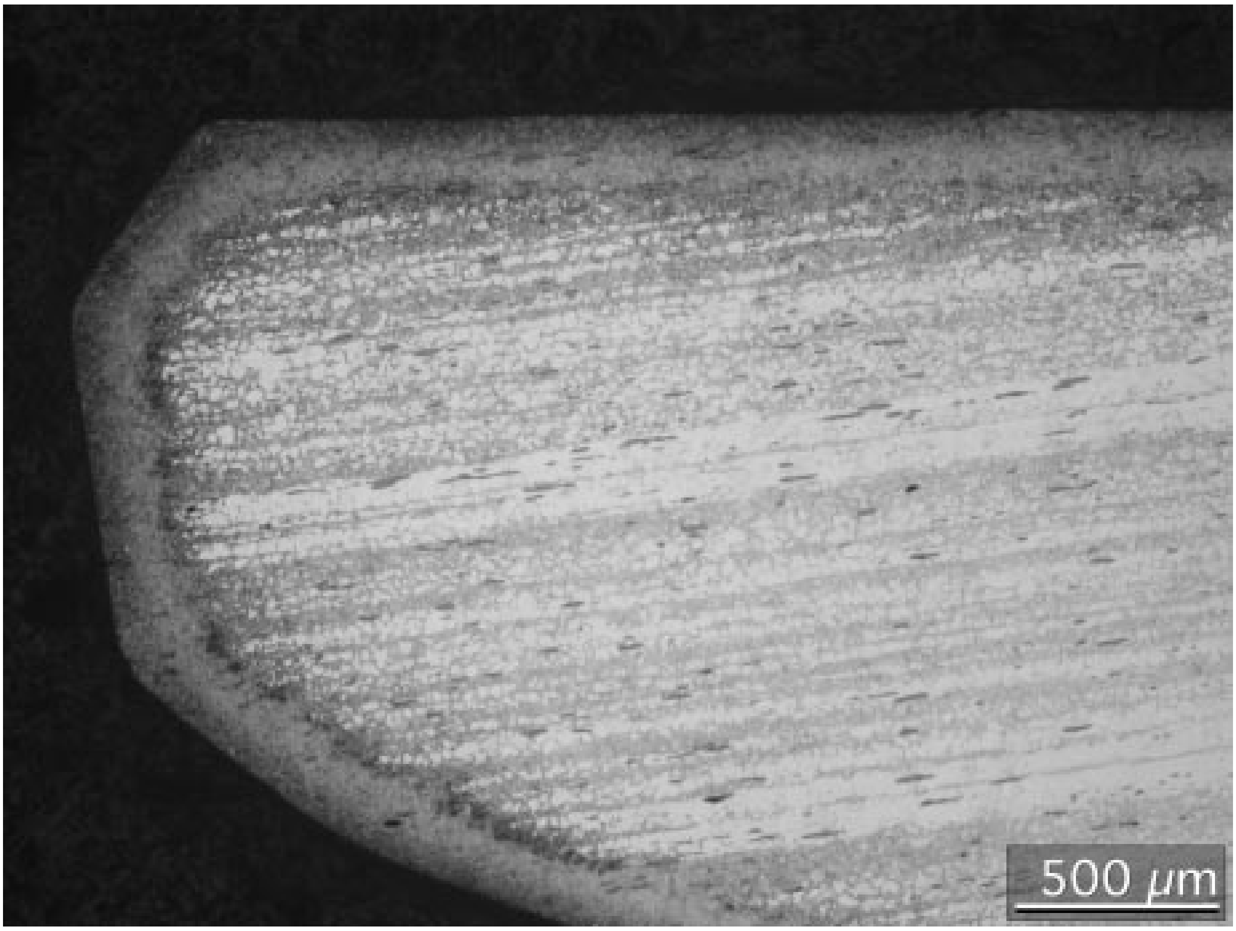


(a)

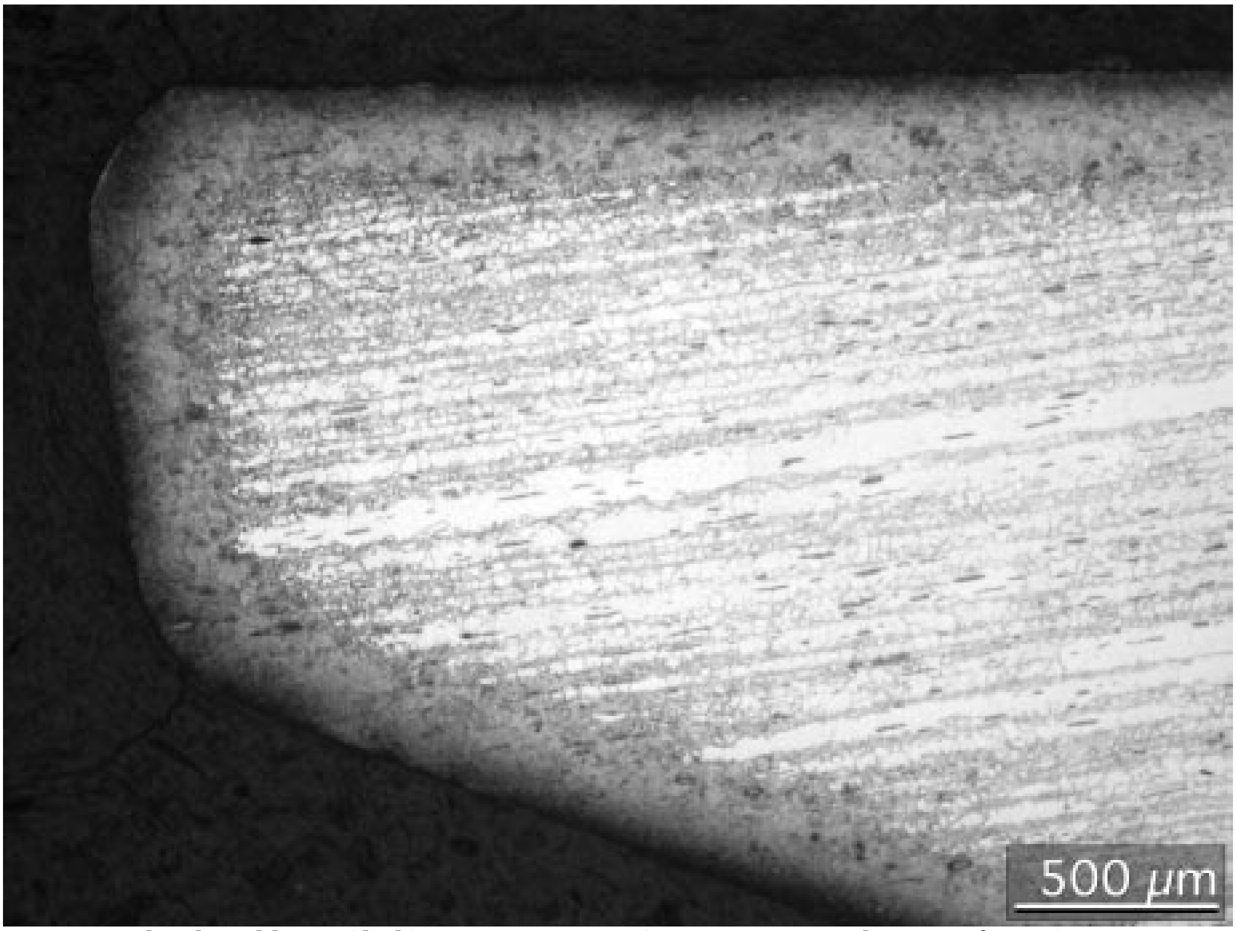


(b)

Fig 4. Case hardened layer (dark) on a spring seat (cross section is shown in fig. 2c), (a) Cylinder 3, (b) Cylinder 4. Optical microscope.

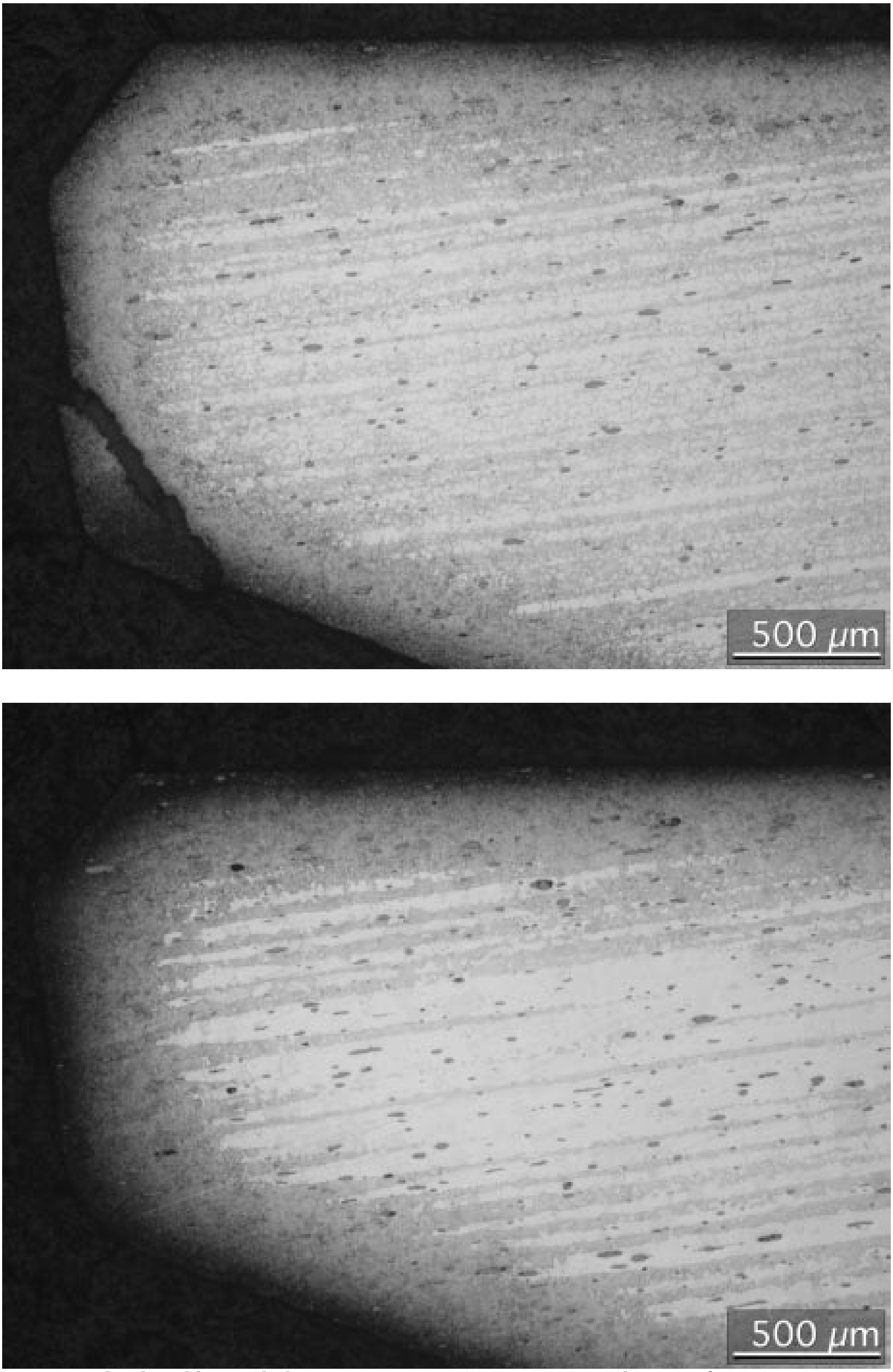


(a)



(b)

Fig 5. Case hardened layer (dark) on a spring seat (cross section is shown in fig. 2c), (a) Spring seat SMP, (b) Spring seat KLI. Optical microscope.



(a) (b)

Fig 6. Case hardened layer (dark) on a spring seat (cross section is shown in fig. 2c), (a) Spring seat “WITHOUT CODE”, (b) Spring seat KLI-0. Optical microscope.

Table 2. Measured and average Vickers micro hardness (HV 0,5) of the case hardened layer of the spring seats. Hardness profiles (according to average hardnesses) are shown in figure 7.

Spring seat	Distance from the surface µm	Measured hardness values HV 0,5			Average HV 0,5
Cylinder 1 LW10077 17328 33-04	100	539	554	565	**553**
	130	442	460	528	**477**
	150	483	536	554	**524**
	180	411	429	401	**414**
	210	448	323	362	**378**
	240	339	325	300	**321**
Cylinder 2 LW10077 17328 33-04	100	539	509	552	**533**
	130	513	473	495	**494**
	150	483	511	488	**494**
	180	470	502	475	**482**
	210	423	486	523	**477**
	240	311	310	233	**285**
Cylinder 3 LW10077 17328 33-04	100	580	497	523	**533**
	130	490	554	442	**495**
	150	509	526	486	**507**
	180	362	331	302	**332**
Cylinder 4 LW10077 17328 33-04	100	580	619	603	**601**
	130	574	580	541	**565**
	150	580	577	574	**577**
	180	544	552	579	**558**
	210	438	436	511	**462**
	240	425	368	411	**401**
LW 10077SMP	100	862	878	793	**844**
	130	736	831	704	**757**
	150	597	649	640	**629**
	180	416	495	436	**449**
	210	409	401	362	**391**
	240	258	323	215	**265**
LW 10077 KLI	100	757	629	749	**712**
	130	696	749	724	**723**
	150	688	642	646	**659**
	180	636	585	619	**613**
	210	539	506	446	**497**
	240	423	399	420	**414**
WITHOUT CODE	100	757	775	736	**756**
	130	736	716	728	**727**
	150	585	685	696	**655**
	180	607	636	666	**636**
	210	585	458	526	**523**
	240	591	580	578	**583**
LW 10077 KLI-0	100	704	736	674	**705**
	130	666	629	663	**653**
	150	626	583	557	**589**
	180	581	632	616	**610**
	210	594	568	613	**592**
	240	580	577	579	**579**

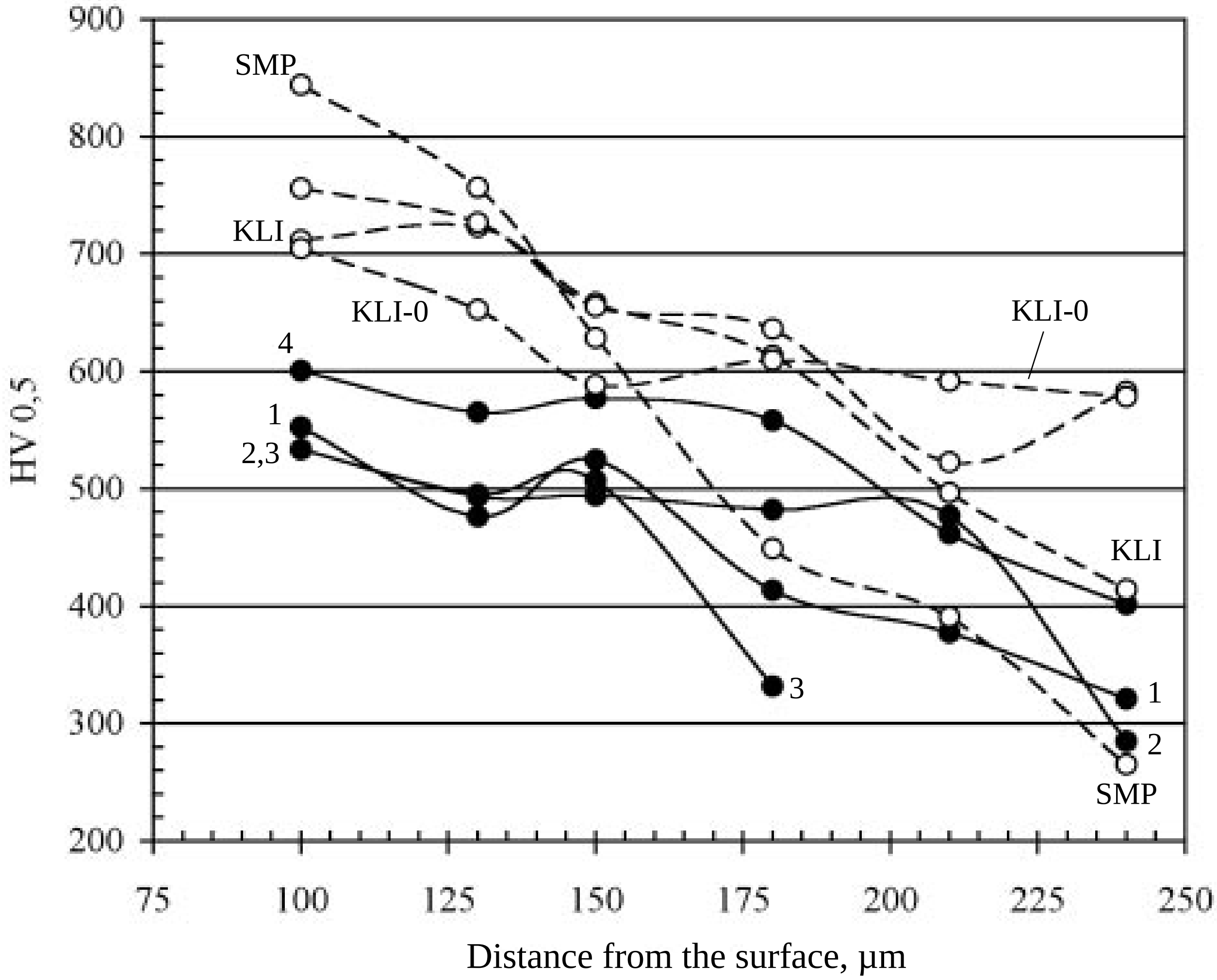


Fig 7. The hardness profiles of the case hardened layer of the spring seats. Cylinders 1-4, black circles and continuous lines. Reference spring seats (KLI, KLI-0, WITHOUT CODE, SMP), white circles and dashed lines. (Values in table 2).

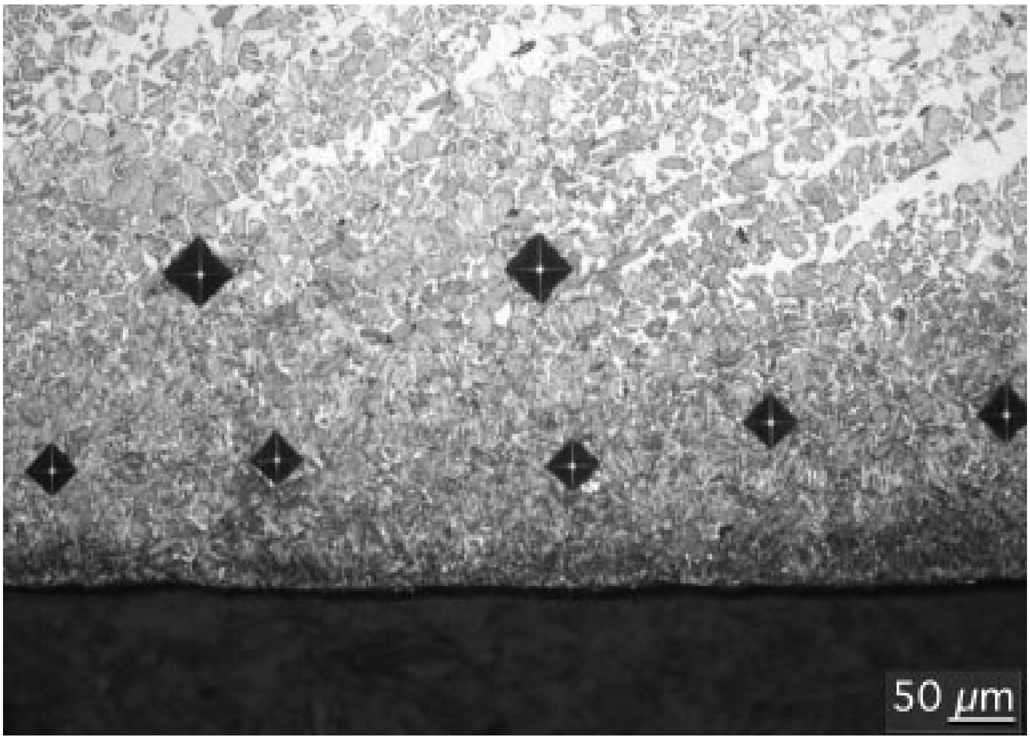


Fig 8. Vickers (HV 0,5) indentations on the case hardened layer of the spring seat (cylinder 2) (the measuring site is shown in fig. 2c). Optical microscope.

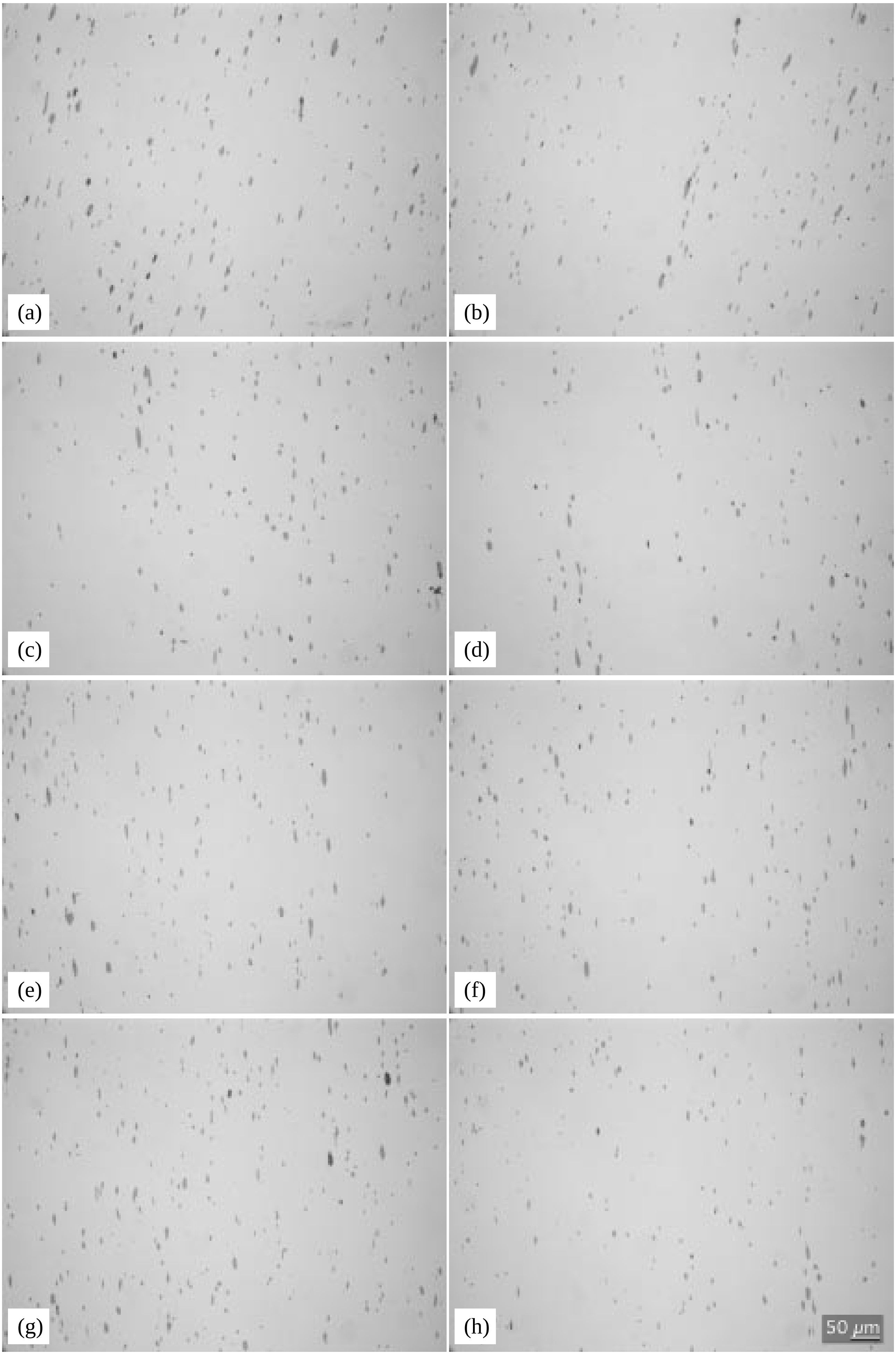


Fig 9. Inclusion structures of the spring seats (cross section in fig. 2c). (**a,b**) Cylinder 1, (**c,d**) Cylinder 2, (**e,f**) Cylinder 3, (**g,h**) Cylinder 4. Inclusion analysis in table 3. Ground and polished surface. Optical microscope.

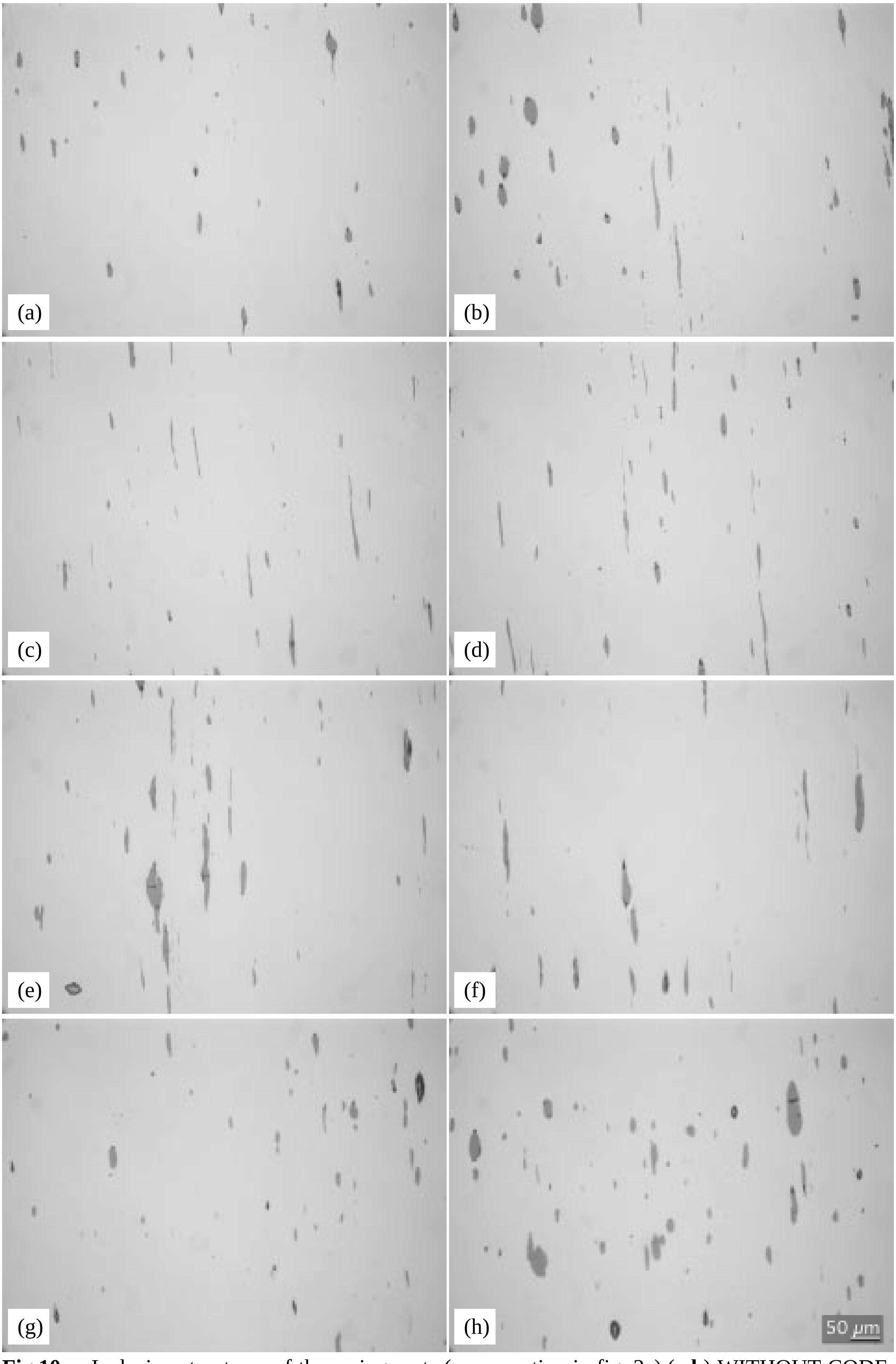


Fig 10. Inclusion structures of the spring seats (cross section in fig. 2c).(**a,b**) WITHOUT CODE, (**c,d**) KLI, (**e,f**) SMP, (**g,h**) KLI-0. Inclusion analysis in table 3. Ground and polished surface. Optical microscope.

Table 3. Distribution of the manganese sulfides in the spring seats according to the inclusion analysis of the digital image analysis. The image frames used in the calculations are shown in figures 12 and 13.

Spring seat	Area fraction %	Number of inclusions pieces	Number of inclusions pieces/mm^2	Average length µm	Average width µm	Average area µm^2
Cylinder 1 LW10077 17328 33-04	1,8	567	639	9,1	3,6	28,3
Cylinder 2 LW10077 17328 33-04	1,4	397	447	8,8	4,0	31,5
Cylinder 3 LW10077 17328 33-04	1,6	507	571	9,2	3,5	28,1
Cylinder 4 LW10077 17328 33-04	1,5	470	530	8,0	3,4	24,1
LW 10077SMP	1,8	165	186	19,4	3,8	97,9
LW 10077 KLI	1,1	204	230	14,7	2,9	47,4
WITHOUT CODE	1,4	185	208	13,5	4,1	71,0
LW 10077 KLI-0	2,0	153	172	17,2	6,0	118,9

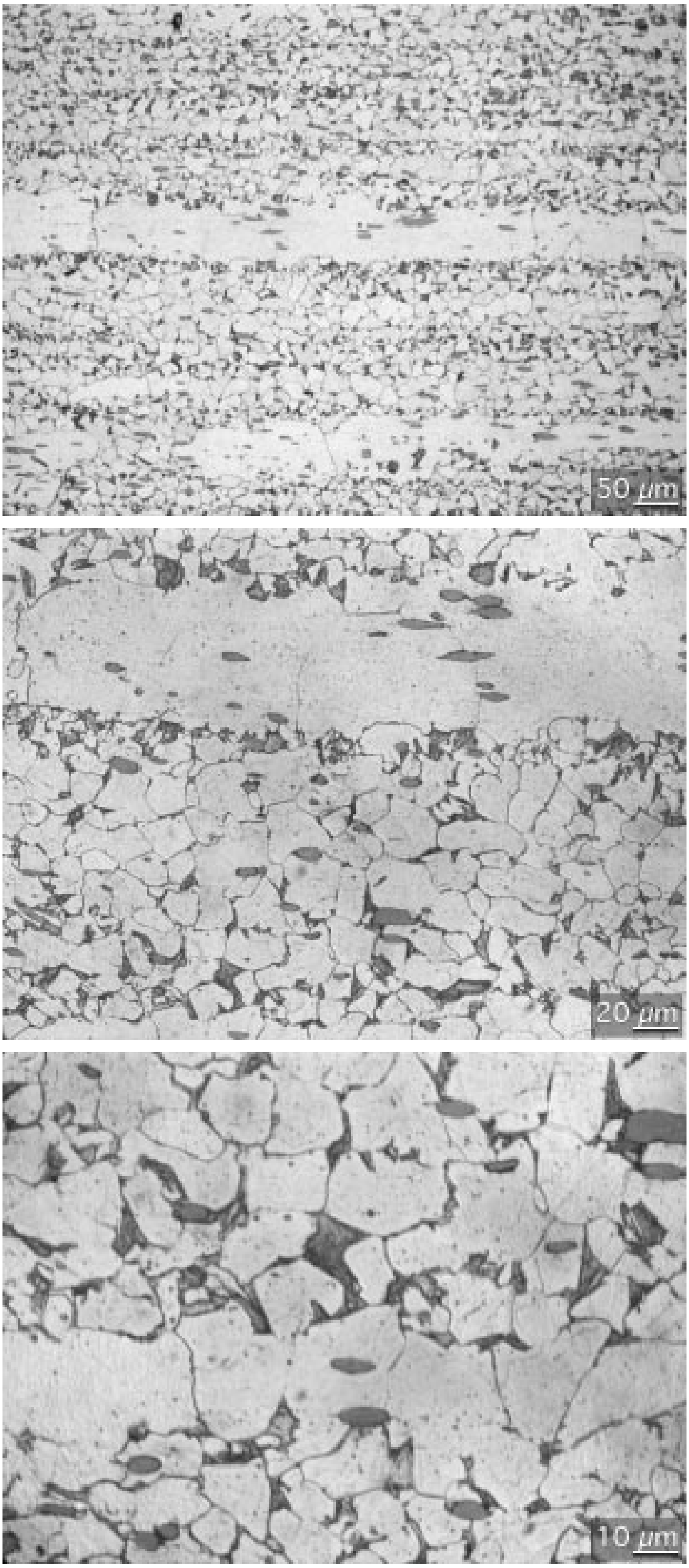


Fig 11. Micrograph of the spring seat core (cylinder 1). Optical microscope.

(a)

(b)

(c)

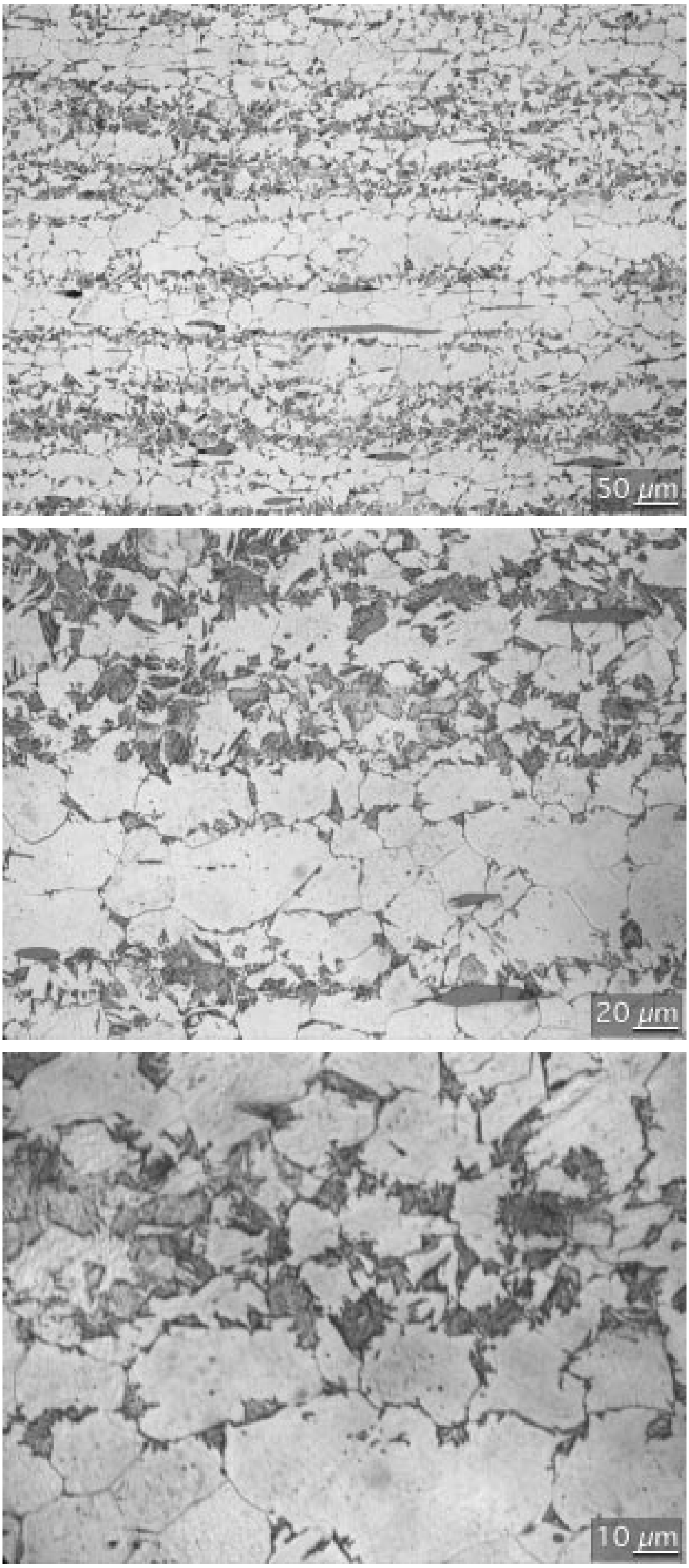


Fig 12. Micrograph of the spring seat core (SMP). Optical microscope.

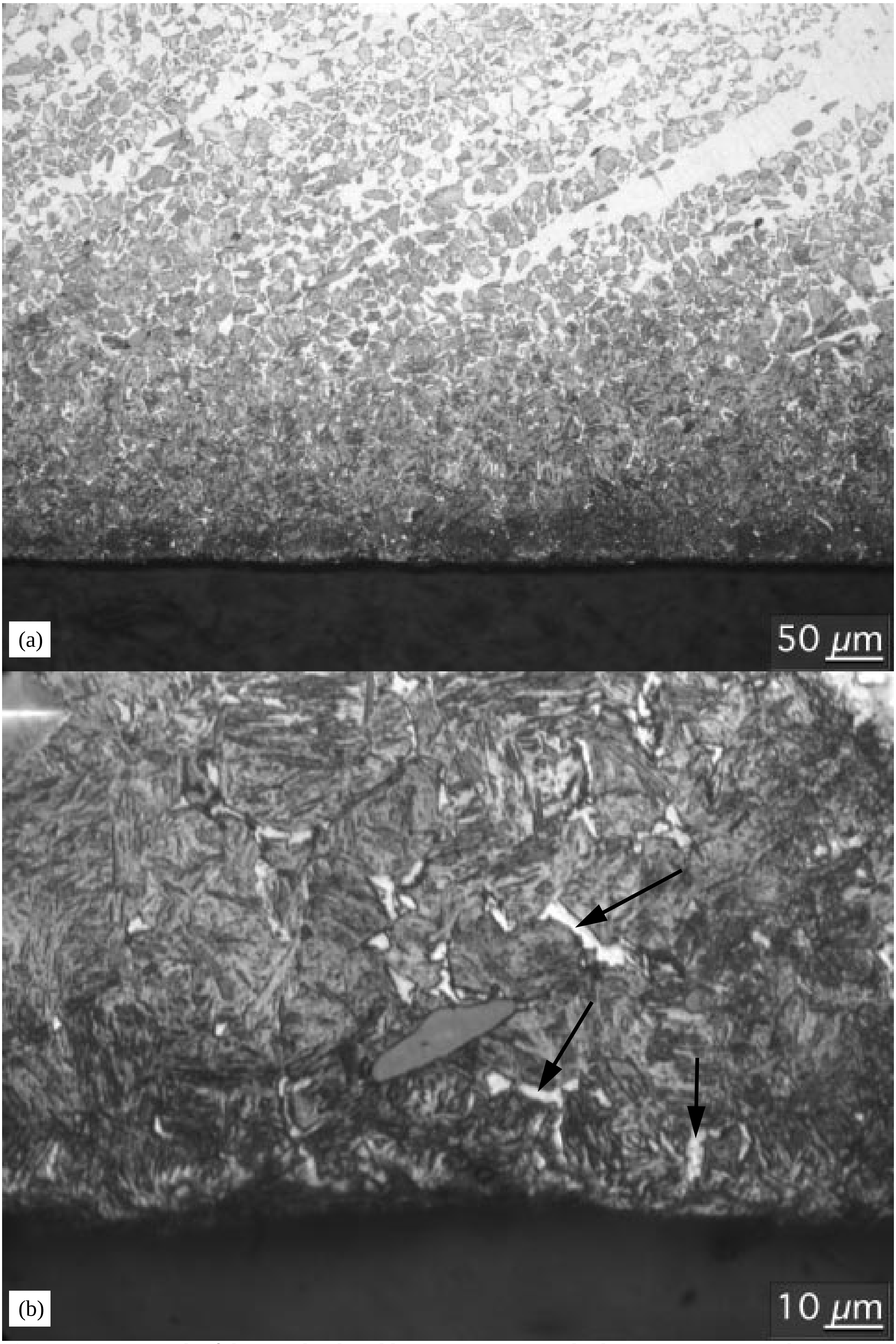


Fig 13. Micrograph of the case hardened layer spring seat (cylinder 2). Ferrite network (arrows in figure b) extends into the surface of the case hardened layer. Optical microscope.

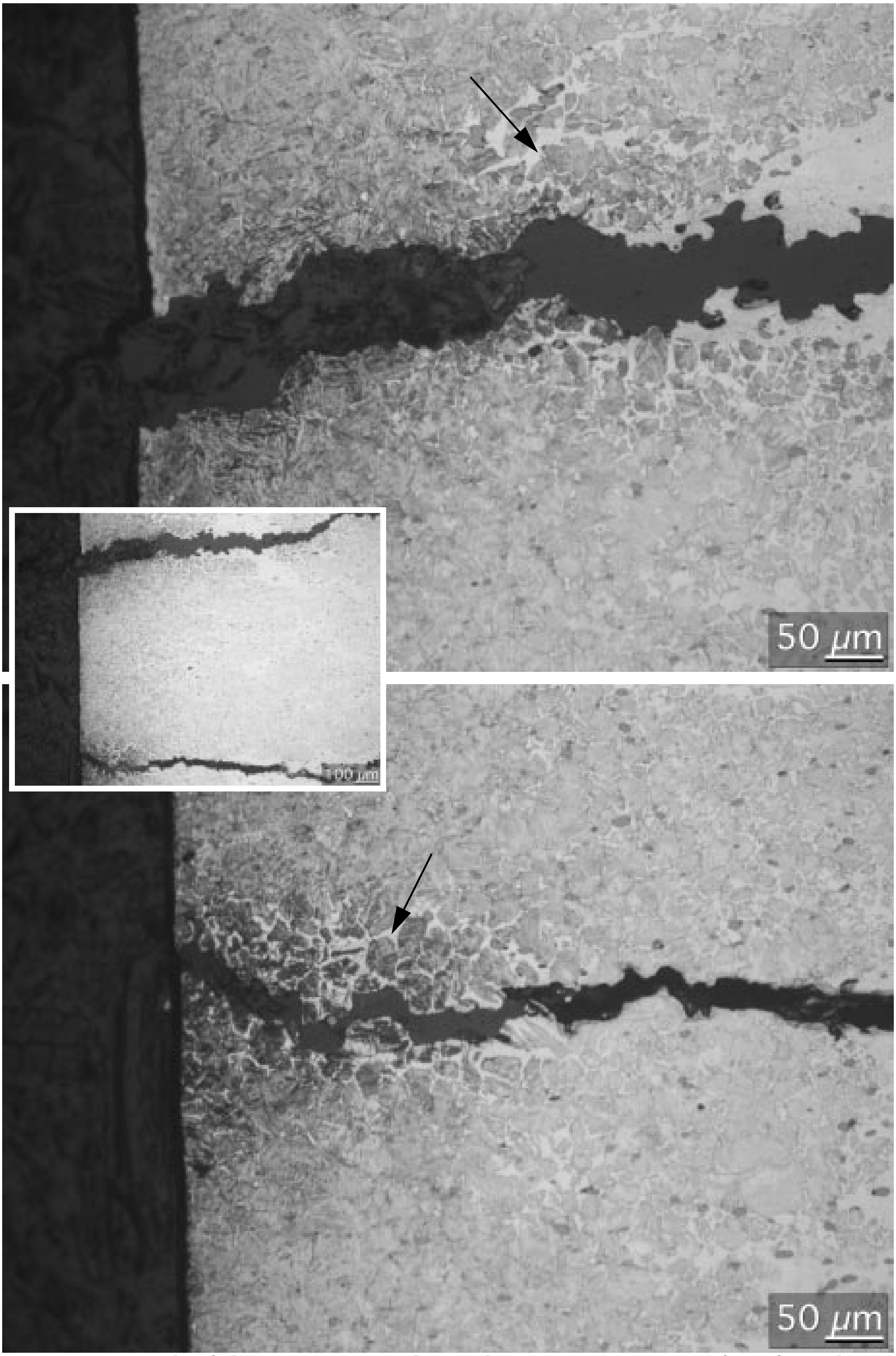


Fig 14. Micrograph of the spring seat at the crack site (cross-section in fig. 2f). Light areas (arrows) are ferrite. Optical microscope.

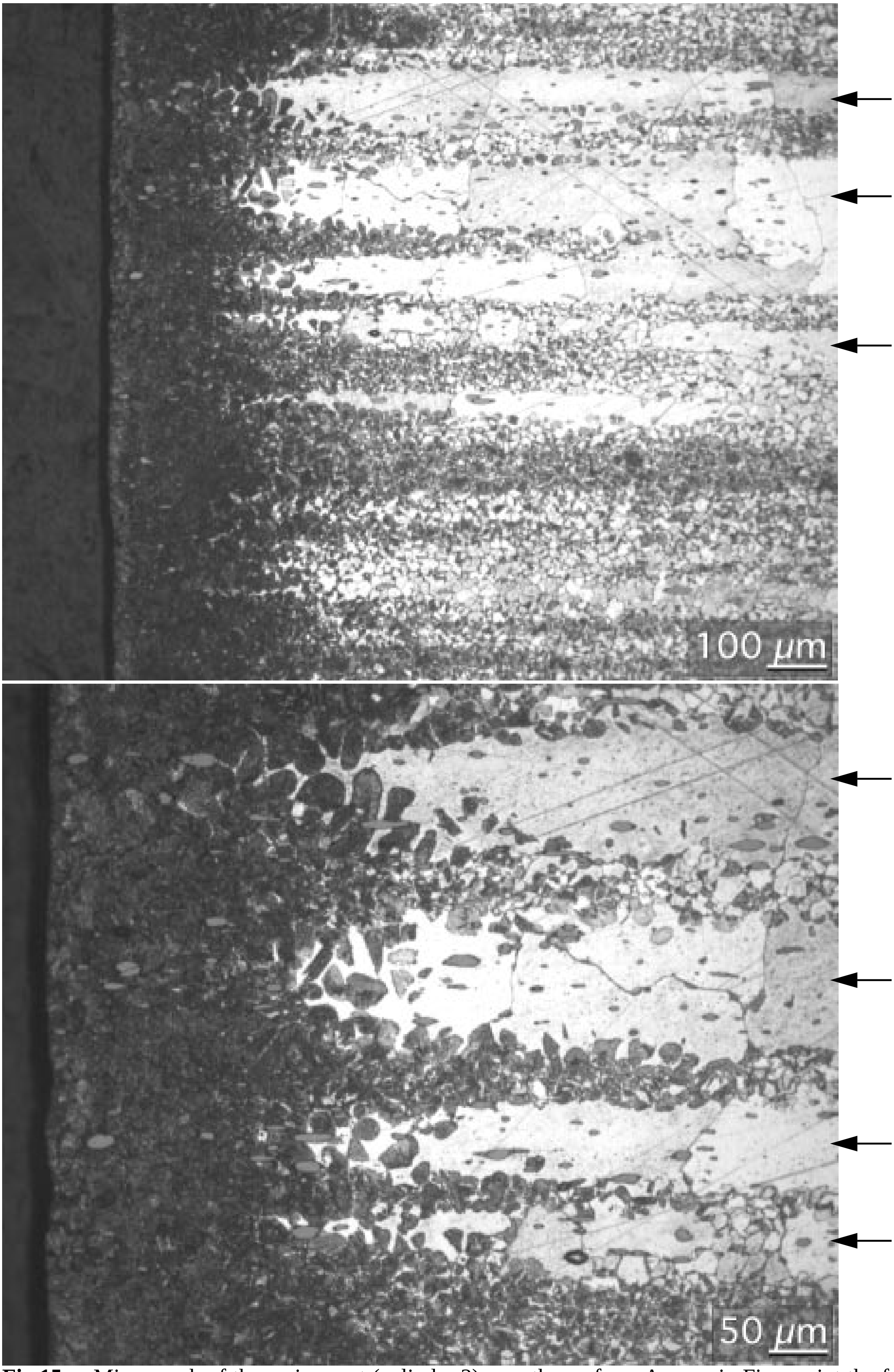


Fig 15. Micrograph of the spring seat (cylinder 2) near the surface. Arrows in Figs. point the ferrite bands with large grain size. Optical microscope.

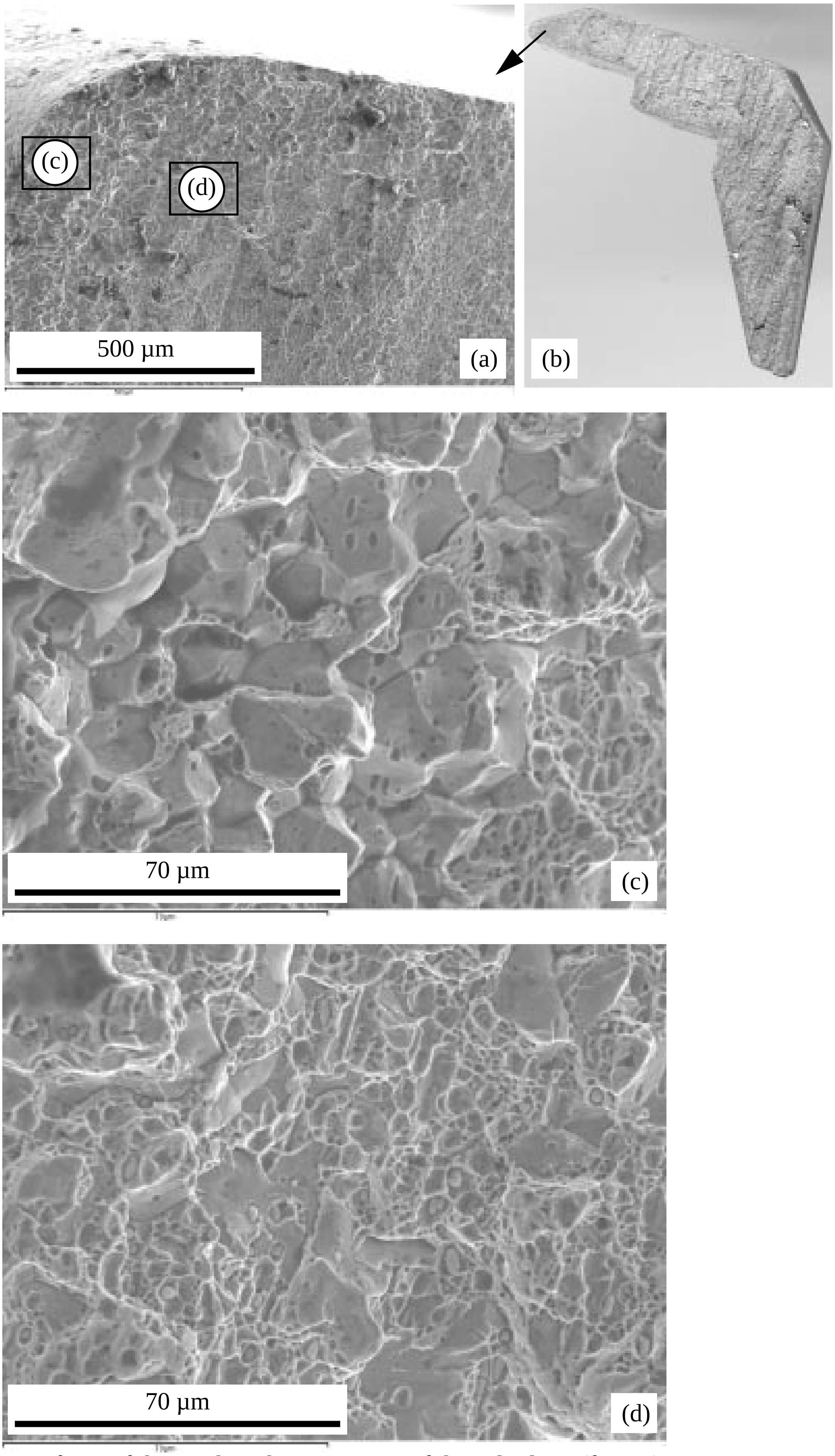


Fig 16. Fracture surfaces of the crack in the spring seat of the cylinder 4 (fig. 2g). SEM.

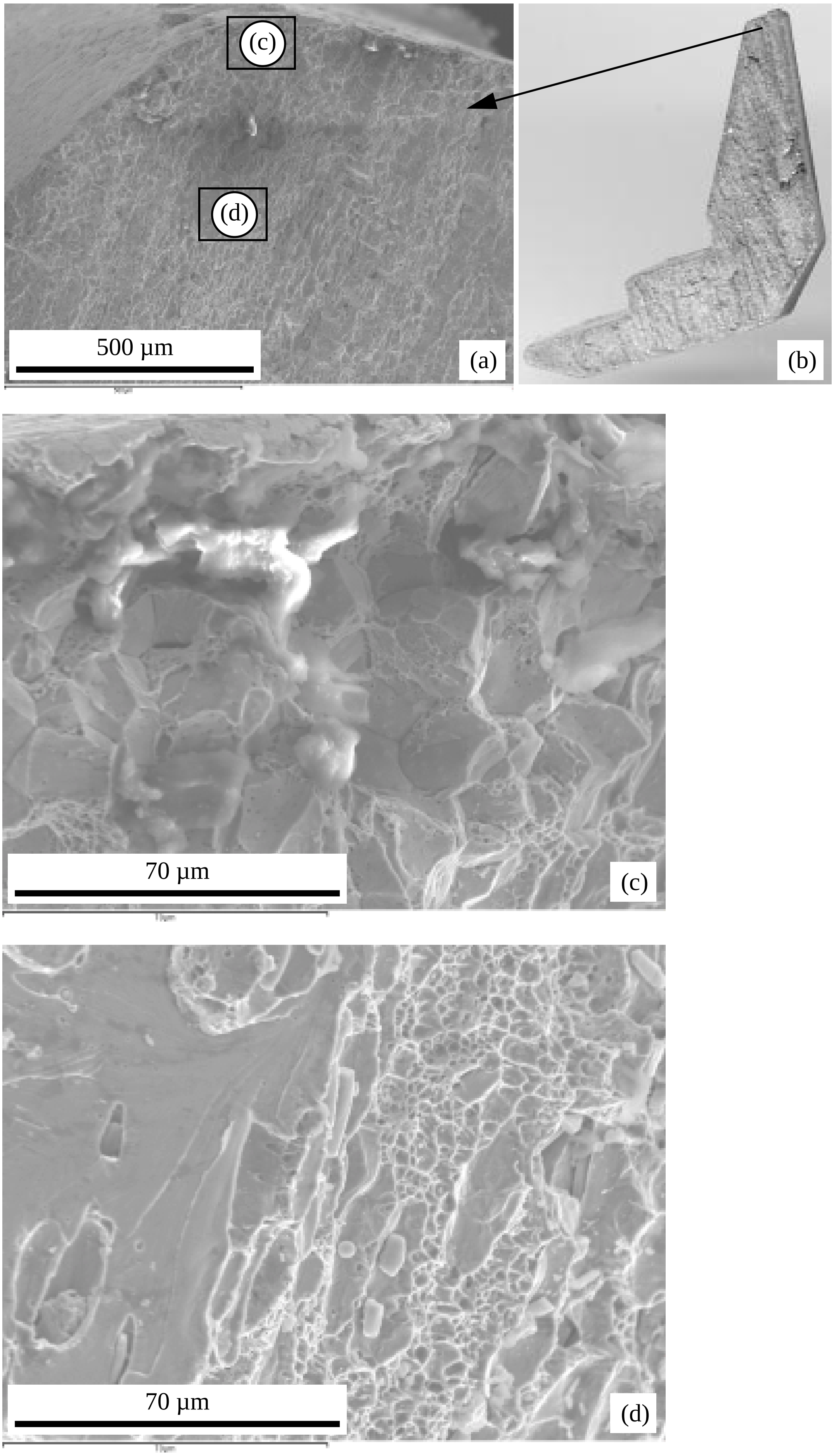


Fig 17. Fracture surfaces of the crack in the spring seat of the cylinder 4 (fig. 2g). SEM.

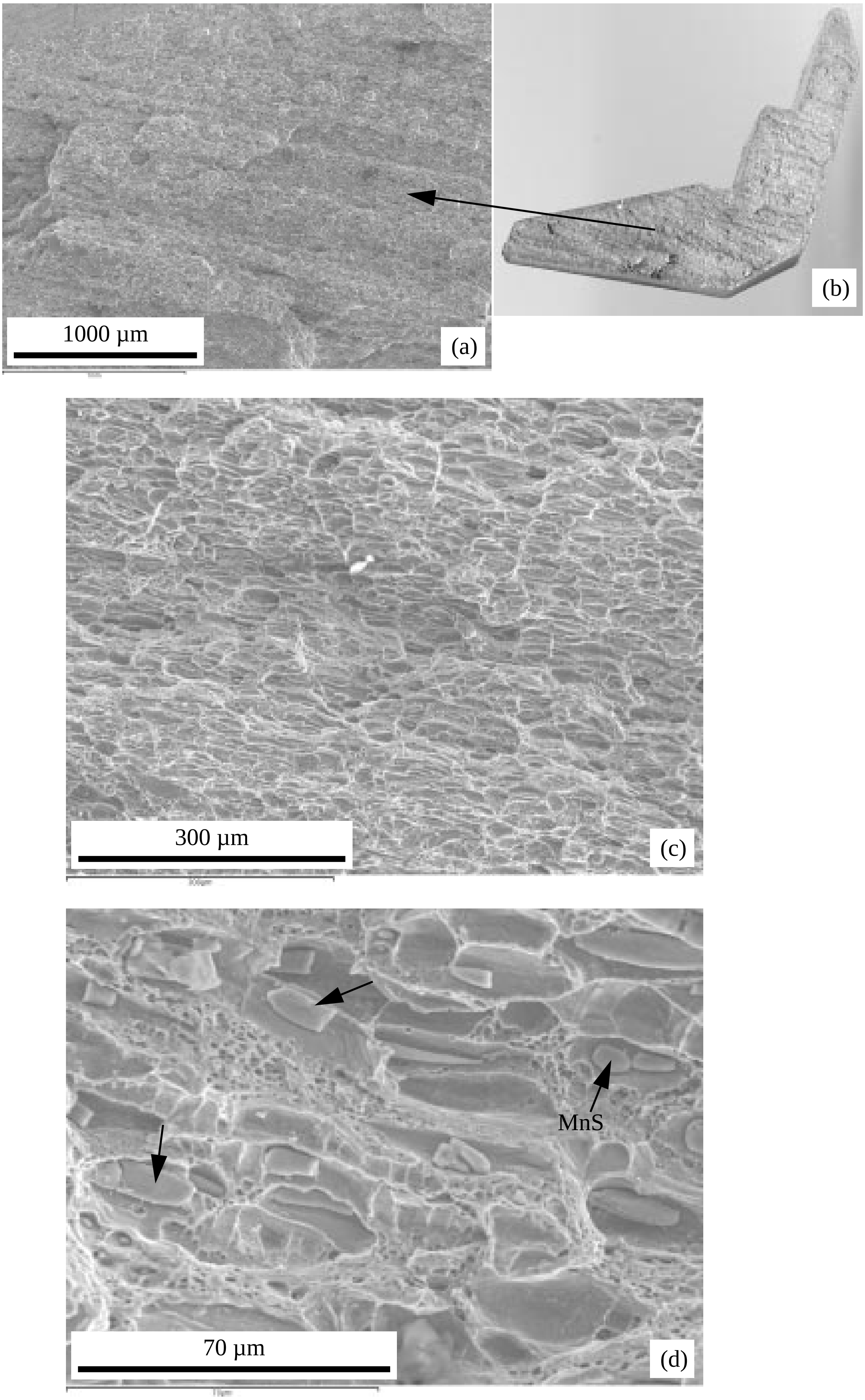


Fig 18. Fracture surfaces of the crack in the spring seat of the cylinder 4 (fig. 2g). SEM.