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KA-32A11BC HELICOPTER IN CANADA: LESSONS OF LOGGING

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Introduction

On January 11, 1980, the experimental helicopter, a retrofitted naval prototype, which was marked with an insignia of two polar bears on its cockpit bow, a Ka-32 emblem on its side, and electrons orbiting a nucleus on its radome, first hovered over the Kamov Design Bureau's airfield. Nikolai Bezdetnov, the Honored Test Pilot and Hero of the Soviet Union, was at the aircraft controls. Less than three weeks later, Bezdetnov landed the helicopter on the deck of the nuclear ice-breaker *Sibir* to give the ship a night look-out capability on her voyage through the vast ice fields of the Arctic Ocean. This is how the model–Ka-32 helicopter came into being.

The rotorcraft was conceived as a multipurpose machine for the national economy. Logging, that is, hauling harvested timber from highland sites was one of its first tasks. In 1982 during 72.5 flight hours, the experimental Ka-32 helicopter made 587 cycle runs hauling 1663 cubic meters of timber from the tree-felling plot in the Caucasian foothills.

With regard to logging, the first away-from-home testing ground for the KAMOV Company's rotorcraft was Switzerland. Here, the Ka-32 participated in clearing away the trees devastated by the storm on February 23, 1990, in the Alps.

Since 1990, Ka-32 helicopters had been used for transporting underslung loads in the hills of Papua New Guinea and other island states of the Pacific region.

In 1991 and 1992, an assessment of the Ka-32 helicopter in logging operations was organized by the VIH Logging, Ltd., near the Lake of Cowichan in British Columbia. The results of the trial operations convinced the Company's President, Mr. Kenneth Nori, and test pilots that it was the aircraft they needed.

The joint effort with this enterprise and the Transport Ministry of Canada resulted in the creation of the model Ka-32A11BC helicopter compliant with the FAR-29 and FAR-33 requirements of the United States.

In April 1997, two Ilyushin Il-76 transport flights from Russia landed in Canada at the Victoria International Airport of the provincial capital city of British Columbia, bringing the Kamov Company-built nos. 31585 and 31594 model Ka-32A11BC helicopters on board. On May 11, 1998, the Ministry of Transport of Canada issued Type Certificate no. H-100 for the model Ka-32A11BC helicopter and Type Certificate no. IE-35 for the model TV3-117VMA engine. In February 1999, the helicopters, which by that time had been equipped with the two-chamber RS-60F hydraulic actuators, received the registration from the Ministry of Transport of Canada and marked C-FIGR and C-GKHL on their fuselage.

Once in Canada, the Russian helicopters were promptly dispatched by the VIH Logging to the remote and sparsely populated base areas on the Country's East Coast. As time went by, the utilization rate of the aircraft grew (Figs. 1, 2).

In May 2000, the VIH Logging started to operate the third model Ka-32A11BC helicopter, no. 31600 (C-GURI). By the end of 2000, the fleet totaled 12 500 flying hours (Fig. 3) and 133 000 logging cycles, while hauling more than half a million tons of fine wood on their underslung load-carrying system.

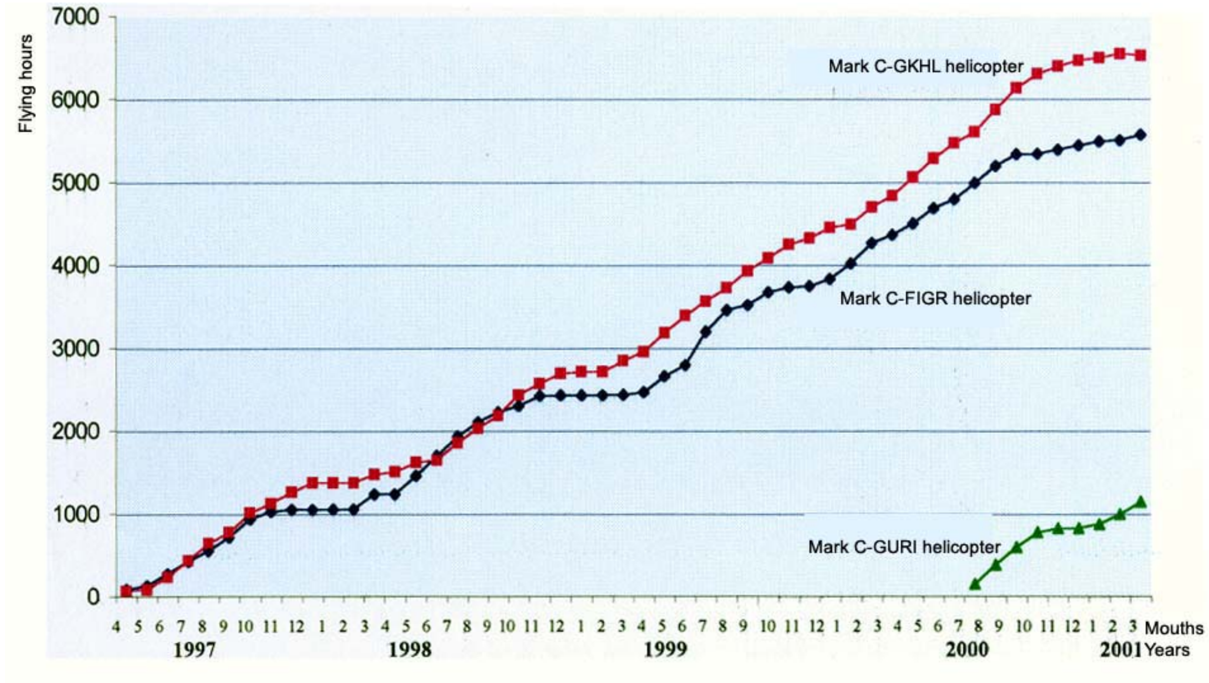

FIG. 1. CUMULATIVE FLYING TIME OF THE KA-32A11BC HELICOPTERS

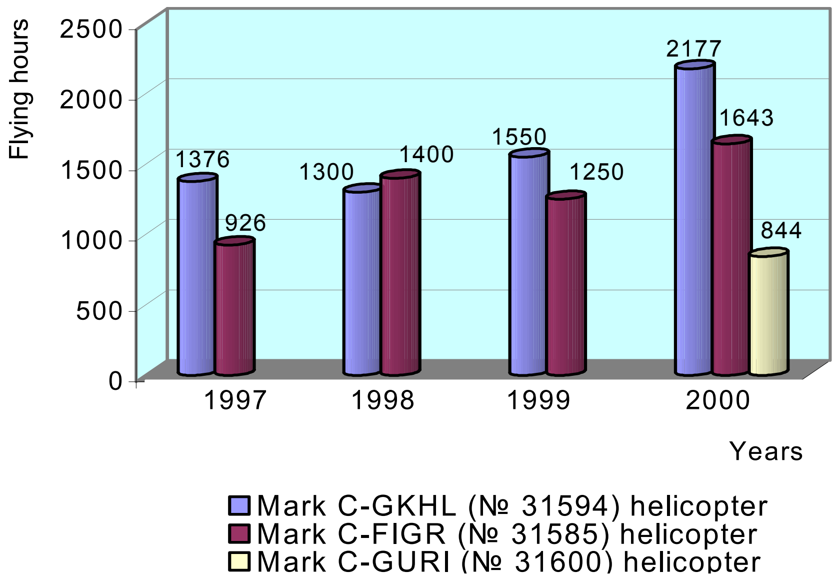

FIG. 2. ANNUAL UTILIZATION OF THE KA-32A11BC HELICOPTERS

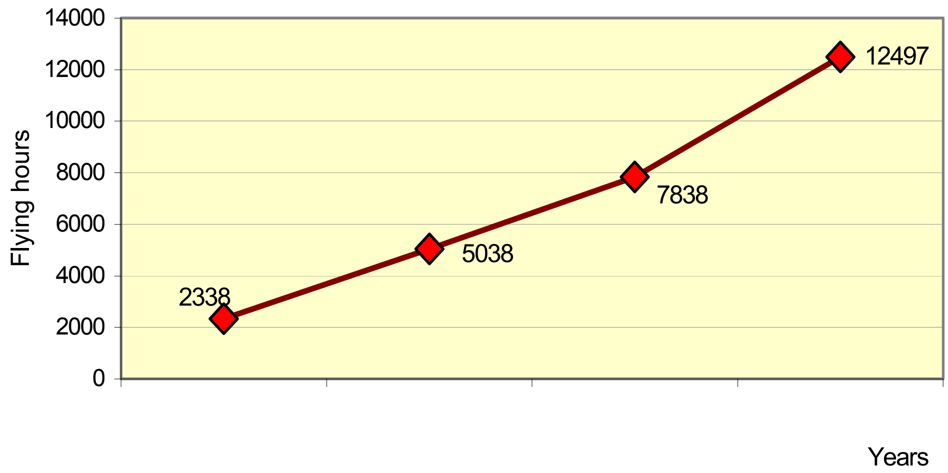

FIG. 3 CUMULATIVE OPERATING TIME OF THE HELICOPTER FLEET

The following two groups of factors ensured the high efficiency of the Ka-32A using its underslung load-carrying system in the mountains.

The first are the known advantages of the coaxial scheme:

- the absence of the tail rotor and the small aircraft size which enhances flight safety near obstacles and enables the pilot to take off and land on a tiniest of sites;

- the excellent flying qualities resulting, among other reasons, from the absence of any crisscross connections in the control system;

- the reduced limitations on the wind speed and direction;

- the high helicopter's hovering efficiency; and other capabilities.

The second group of factors comprises the high specific engine output power per helicopter unit weight and the altitude characteristics of the model TV3-117VMA engines, which retain the takeoff power up to 2600 m and the 1st cruising regime up to 5600 m (Fig. 4). The hovering ceiling and the climb rate of the helicopter are seen in the nomograms of Figs. 5 and 6.

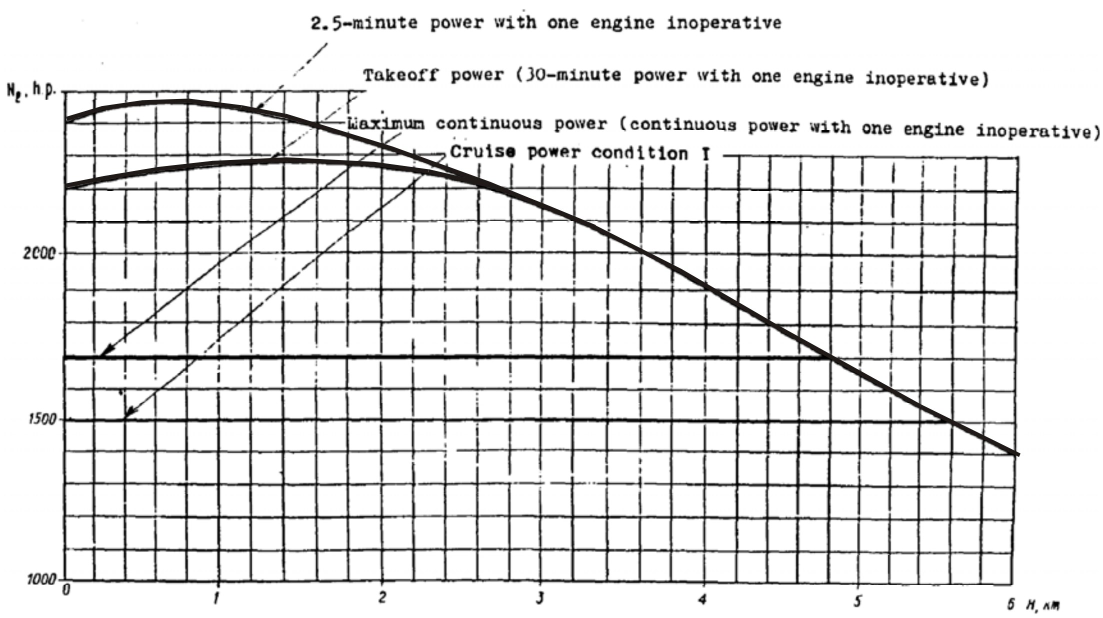

FIG. 4 THE ALTITUDE CHARACTERISTIC OF THE TV3-117VMA ENGINE

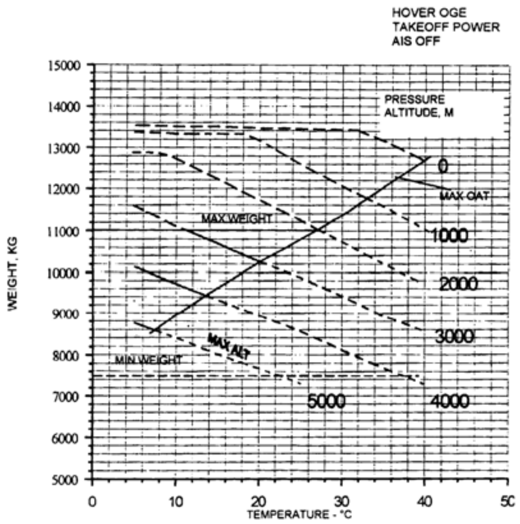

FIG. 5 HOVER CEILING

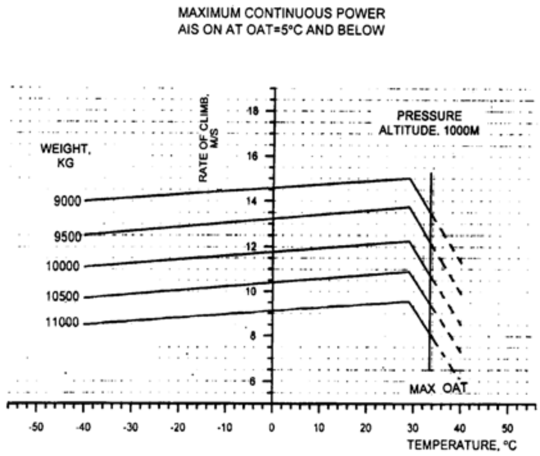

FIG. 6 THE MAXIMAL CLIMB RATE

Conditions of Logging

During logging, the helicopter hauls timber either up and down a mountain slope or from one slope to another. Normally, the logs are stored below the harvesting plot. Hence, a typical logging cycle is a sequence of the following operations:

- the engagement and the hauling of the load to an elevation of 10–20 m above the ground level;
- the acceleration downhill and a deep glide;
- the deceleration and the releasing of the load;
- the load-free return uphill; and
- the deceleration to hover.

A cycle takes 2–3 min to complete. Roughly once an hour the helicopter is flown for 5–7 min from the workplace to its temporary base for refueling. In addition, a fraction of the flying time is expended on a ferry flight to a new base and to the scheduled maintenance center. Occasionally, a helicopter may be assigned a fire fighting or some other task. This is why the flying time per logging cycle differs significantly from the duration of a normal logging cycle. Table 1 shows the data on the operations of the helicopters in Canada by the January 25, 2001.

Table 1

Helicopter	First flown in Canada	Flying hours	Landings	Cycles	Mean cycle, min
C-FIGR	Apr 09, 1997	5367	5398	39535	8
C-GKHL	Apr 11, 1997	6397	5806	75920	5
C-GURI	July 20, 2000	950	924	16436	3,4

The helicopters are used for logging only in fair-visibility daylight conditions. Compared to plains, mountain valleys see a belated sunrise and a premature sunset. The winter daytime is 7–8 hours. Moreover, encroachments of dense morning mist in valleys are not infrequent. In summer, the health authorities set the daily maximum of 10 flying hour for a crew of two. Christmas is the holiday almost for everybody. For instance, sometimes, the conservationists ban helicopter flights during the mating season of bears.

The experience of Mr. Tracey Horsman, the Deputy Director of the VIH Logging, and the technician of one of the helicopters, supports the following account for the 365 days of the year:

- 94 days lost for poor weather, averaging two days a week;

- 24 days expended for the scheduled replacements of the engines, the gearbox, the rotor mast, and the hydraulic actuators;
- 14 days allocated for the Christmas Holidays;
- 132 days totaling for all of the above (94+24+14 = 132);

and

- 233 days, on average, available for helicopter logging operations (365 – 132 = 233), or roughly 2200 hours (Fig. 7).

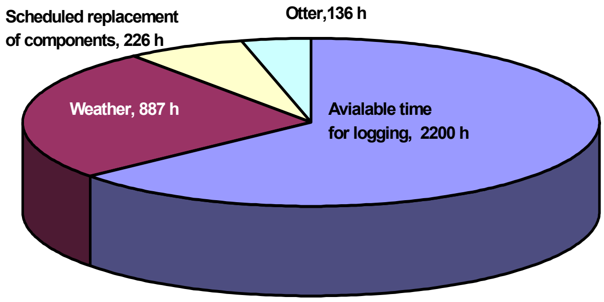

FIG. 7 ANNUAL DAYLIGHT HOURS

In the year 2000, the utilization of the C-FIGR and C-GKHL helicopters reached 1640 and 2140 flying hours, respectively. This means that the C-GKHL helicopter utilized virtually its entire available summer time. The coefficient of technical readiness of this aircraft reached 90%.

Such a tight operating schedule of the model Ka-32A11BC helicopters in Canada was met in spite of the extremely tough conditions imposed by the logging on some of the mechanisms and the occurrence of their failures unknown from the previous experience.

Upper Rotor Blades

The upper rotor blades were designed by the KAMOV Company and are manufactured by the Kumertau Aviation Production Association. The service life of these blades was 3000 hours and 12 calendar years, whichever should be reached first.

On August 30, 1998, during hover, the crew of helicopter no. 31585 carrying underslung load felt a sharp rise in the vibration, terminated the operation, and landed. The inspection on the ground gave no result. The nuts on the rotor mast were tightened as a precautionary measure aimed at eliminating a possible vibration cause, followed by a flight test. The level flight was normal; however, the engagement of the load again ended up in a strong growth of the vibration. On the ground, a thorough inspection revealed a cracked leading-edge part of the upper blade spar opposite the fifth hub-to-tip trailing-edge section of the profile. Damaged upper-rotor blade logged 1788 h 29 min.

On October 21, 1998, during the check on the same helicopter in similar circumstances, another such crack was found. Damaged upper-rotor blade had the flying time of 1329 h. In both cases, the crack originated in the spar zone adjacent to the hub-facing end of the first steel balancing weight installed in the leading-edge part of the blade spar.

One of the causes of the fatigue damage to the spar were the high stresses developing in the blade during the deceleration, when the underslung load was just to be released during the recovery of the helicopter from the fast descent. In this regime for up to 15 s, the stresses reach 2.8 kg/mm^2, whereas during a normal flight at a speed within 200–220 km/h, the stresses do not exceed 2.2 kg/mm^2. During transport flights, acceleration takes up only a small fraction of the time. During logging operations, acceleration is repeated every 2–3 min.

The AR MAK (the Aviation Register of the Interstate Aviation Committee) in its Airworthiness Directive no. 98-001-065 issued on November 14, 1998, introduced an additional limit of 13 000 flight logging cycles for the upper-rotor blades of the model Ka-32A11BC helicopter. When the investigations into the possible causes of the occurrence of cracks in the spar of the upper-rotor blade were ended, related Airworthiness Directive no. 2000-065-01 was issued on January 31, 2000.

Since then, no spars developed cracks in operation. The upper-rotor blades have now reached 3000 flying hour in the logging operations.

Main Rotor Hubs

During a downhill acceleration and the subsequent transition to a steady low-altitude glide at a moderate engine power, the flying regime of the helicopter nears autorotation, with the blades moving co-rotationally to a large angle. When the forward speed and the vertical speed decrease, the engine power rises and the blades regain their normal position. This is why the blades make an intensive forward-backward sweep in the plane of rotation around the vertical hinge. The result was the two types of faults.

The rate of wear of the KOMPONOR antifriction layer of the metal—polymer bearing—dampener in the vertical hinge grew. The hinge was designed for small, about 20', angular oscillations of the blades in the plane of rotation. This damage mode was first detected in field operations in August 1997, when helicopter no. 31594 developed an elevated vibration in flight as a result of the disintegration of the polymer layer of all three bearings of the vertical hinge in the upper rotor hub having 723 operating hours.

The sharp increase in the angle to which the blade turns around the vertical hinge during the deep glide raises the forces acting on the thrust bearing.

As a temporary preventive measure against this failure, the task of replacing these bearings on the attainment of 500—600 operating hours was introduced in service.

Model VR-252 Gearbox

The VR-252 gearbox was designed jointly by the Klimov Works and the Kamov Company. The gearbox is manufactured by the Krasnyi Oktyabr' Company based in St. Petersburg which assigns 1500 h for the service limit and 500 h for the time to the first overhaul of the gearbox. The existing service bulletin enables the manufacturer to increase the time to the first overhaul up to 1000 h on the attainment of each consecutive 100 operating hours, based on the results of the evaluation of the technical condition.

The some 4 years of the Ka-32A11BC operations in Canada saw 5 gearboxes reaching 1000 flying hours.

Compared with the other uses of the model Ka-32A11BC helicopter, the fraction of the flying time characterized by a near-to-takeoff engine power is the greatest. The flight stages in which such power is used are the lifting of the load, the deceleration, the hovering of the helicopter carrying an underslung load, and climb (Fig. 8).

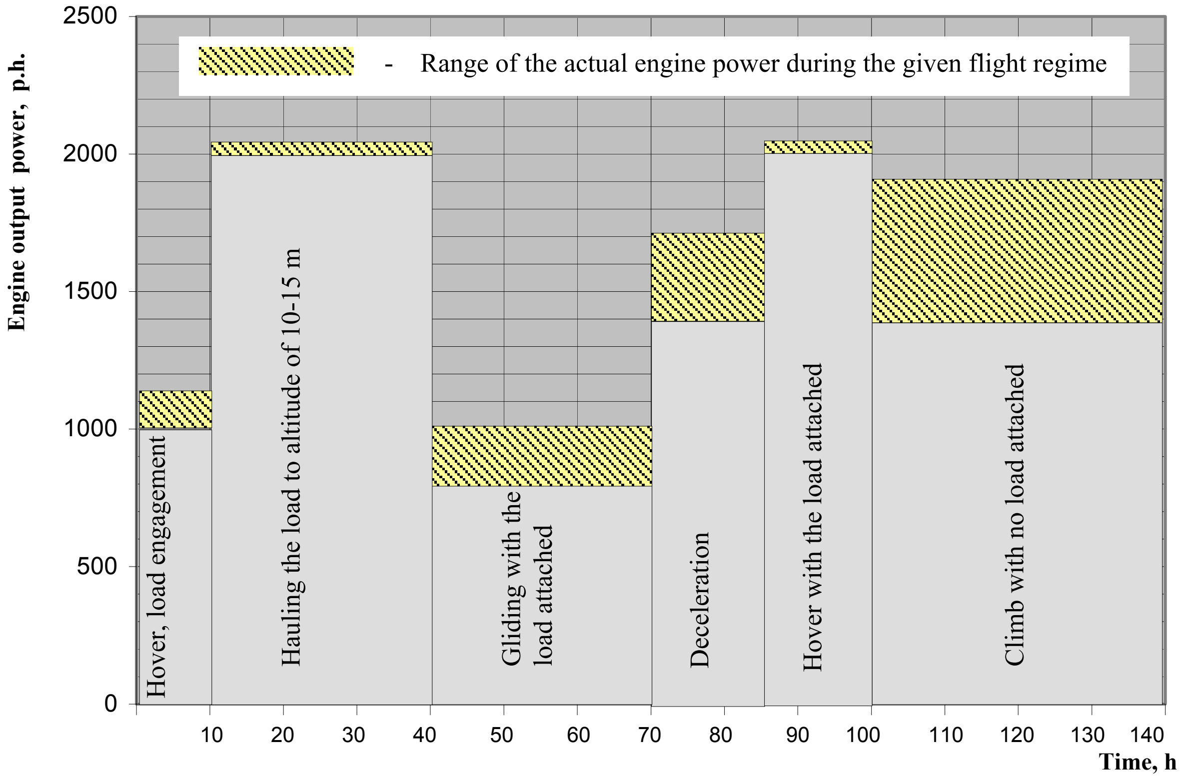

FIG. 8 THE ENGINE OUTPUT POWER DURING ONE CYCLE OF LOGGING OPERATIONS

In climb, the output engine power of a load-free helicopter is dependent on the climb rate and ranges from 1400 h.p. at V_y = 14 m/s to 1900 h.p. at V_y = 24 m/s. In 1999—2000, the latter level grew to 1770 h.p., that is, 20% greater than the related level for normal tasks.

The majority of the occurrences of fault in the gearbox were connected with the wear of the pins which during operation contact the rollers of the pinions. For enhancing the operability the pins, several measures were taken (shot blasting the pins, the matching of the main gear and the pinions within the pitch tolerance , the installation of separators, and other solutions). The pins wear slowly. This condition is detected in a timely way by the on-board test systems.

The fatigue failure of the cogs in the driven helical gear during the logging operations attracted a special attention to the problem of gearbox reliability. This gear transmits the combined torque of the two engines.

On June 1999, the crew of helicopter no. 31585 saw the red CHIPS GEARBOX flashing. The crew stopped the logging operation and landed on the takeoff site. The ground inspection of gearbox showed the presence of chips on the oil filter and on the magnetic chip-capturing plugs. The oil was changed; and during the engine ground run the technician of the helicopter detected an unusual noise in the gearbox. The inspection through the removed breather showed that two adjacent cogs in the driven helical gear were partially broken.

This gear had never failed in the previous operations of the model Ka-32 helicopters. Therefore, the failure was categorized as a one-off occurrence.

Yet another such failure occurred on December 8, 2000, during the operations of model Ka-32A11BC helicopter no. 31594. The CHIP GEARBOX light went off in flight. Traces of metallic particles were detected on the signaling plugs during the inspection on the ground. The gearbox was filled with fresh oil and was operated until chips were detected in the oil again.

The subsequent investigations showed that the fracture was caused by fatigue as a result of variable bending stresses. It was also found that some of the parameters of the damaged gears were quite close to the boundaries of the tolerance or even beyond them (the content of sulfur, phosphorous, and some other impurities in the metal; the carbide lattice on the cog surfaces; and the radiuses of the troughs).

The loads during the logging came close to the limiting level determined by strength, and the design was incapable to withstand even a small reduction in strength or a slight increase in the operating load. Moreover, the operability of the gearbox impaired by the use of foreign oil grades, namely, Mobil Jet Oil II, some of whose parameters were inferior to the related parameters of the grade B-3V oil of the Russian make. When the firmness of the lubricating film decreases, the rate of wearing increases, and pits of eroded material appear on the cog surface. These pits become additional concentrators of the bending stresses and decrease the fatigue strength of the cog.

Figure 9 schematically illustrates why the fatigue failures of the cogs in the driven helical gear occurred when the operating time was small. The speed of the gear was 1707 r.p.m. During one operating hour, each of its cogs is subjected to 102 420 loading cycles. This means that 200 operating hours result in 20 million loading cycles. The latter value corresponds to the limit of the bending fatigue strength of the grade 12KhN4-Sh steel. If there had been no gear failure during this or a somewhat greater operating interval, than the fatigue limit for the gear cogs would have been greater than the operating stresses; and the bending fatigue longevity would have been virtually unlimited.

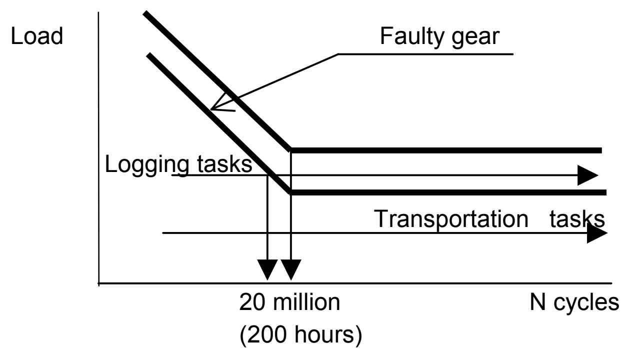

FIG. 9 THE LOAD–LONGEVITY DIAGRAM

In the above cases, the on-board systems and the ground test equipment gave timely information about the failures of the cogs in the helical gear of the gearbox by issuing the CHIPS GEARBOX red light during the flights and enabling the ground personnel to detect the chips on the oil filter and on the magnetic chip-capturing plugs and to determine the abnormal noise in the gearbox zone. There were no changes in the operating parameters of the gearbox, such as an oil-pressure decrease, an oil-temperature rise, or a pressure-difference in the oil filter, during these occurrences. The time between the first signs of the gearbox fault on model Ka-32A11BC helicopter no. 31594 and the detection of the fractured cogs followed by the cancellation of the service operation of the gearbox was 9.7 h. The fractures of either the single cog or the two adjacent cogs neither had any effect on the condition of the gearbox train, nor prevent the helicopter from completing the flight and landing safely on the takeoff site.

The capability of the driven helical gear to operate after failure of several cogs was detected for the first time in 1979 during the bench tests of the gearbox.

A stronger bevel gear was developed. Airworthiness Directive no. 2001-084001 issued on January 12, 2001, by the AR MAK, and Airworthiness Directives nos. CF-2001-09; -10 issued on March 19, 2001, by the Ministry of Transport of Canada, required a stricter monitoring of the technical condition of the gearbox, prohibited the use of any grade of oil other than B-3V oil, and took some additional measures for maintaining the required flight safety level.

Model TV3-117VMA

The model TV3-117VMA engine developed by the Klimov Design Bureau, St. Petersburg is manufactured by the Motor Sich Works, Zaporozh'ye. The TBO and the service life of the engine are 1500 and 3000 h, respectively. High dependability of different versions of the model TV3-117 engines is supported by their long-time operation on a broad scale as part of the model Ka-32, Mi-8, and Mi-24 helicopters.

In addition to the above systems, the logging conditions in Canada turned out to be heavy for the engines as well.

During logging, the helicopter is flown in the regimes of takeoff and gliding which follow each other in a rapid succession. For controlling the helicopter in this way, the pilot resets the collective pitch each time the regime should be changed. Concurrently with the changes in the collective-pitch setting, the speed of the power turbine and the gas generator are changed within the ranges of 84.5–92% and 84–100%. The periodic variations of the centrifugal forces acting on the engine rotating parts cause their low-cycle fatigue. This is especially so for the cover disks. The alternating sharp deceleration and acceleration creates the so-called *advanced acceleration* which results in the engine overfueling. The fuel residence time in the combustion chamber is insufficient for a complete combustion. The result is that the residual fuel is burnt on the nozzle guide vanes and the rotor blades of the turbine. The cyclic changes of the temperature in the hot flow path cause thermal fatigue, deformation, and cracking of the band-cases of the nozzle vane row, the subsequent wear and failure of the nozzle vanes and the power turbine blades.

Some of the environmental factors had a negative effect on the condition of the engines. Thus, the high content of volatile pine pitch in the forest air contributed to the buildup of solid deposits on the nozzle vanes. The formation of clogs on the fuel burners which worsened the fuel atomization may have been caused by the occasional supply and the use of substandard fuel.

Airworthiness Directive CF-2001-11 issued on March 19, 2001, by the Ministry of Transport of Canada requires that the engines of the Ka-32A11BC helicopters used for logging should be periodically cleaned.

Several engine parts including the band-cases of the nozzle vane row were strengthened. For enhancing reliability of the model TV3-117VMA engines, the augmented scheduled task for 500–600 h was proposed. The purpose of this task is to replace the cover disks in the field operating conditions.

Helicopter Overall Reliability

Let us assess the effect of the conditions of the logging operation on the reliability of the entire helicopter and its equipment by comparing the data on the model Ka-32A11BC operated in Canada with the data on various versions of Ka-32 doing other work. In making this comparison, we should take into account that in Russia Ka-32A11BC stands out for its long service life. This enabled the helicopter to exceed 6000 flying hours without being subjected to the major restoration work. The other versions of Ka-32 helicopters have the TBO of 2000 flt h and the service life of 4000 flt h.

The base line for our comparison is the model Ka-32T and Ka-32S helicopters operated in the Republic of Korea. These aircraft are used for fire fighting, sea search-and-rescue, and environment-conservation tasks. By the end of the year 2000, the fleet consisted of 32 helicopters. Since 1997 till the end of the year 2000, the total operating time of the helicopters reached 13 250 h fleet. The latter is slightly more than the related value for the three model Ka-32A11BC helicopters operated in Canada during the same period. Regarding the flying time, the helicopters based in Korea are at significantly early stage of their service life compared to the helicopters operated in Canada. In Korea, the mean total operating time pre helicopter is 500 h; and only two aircraft exceeded the 1000-hour mark.

Figure 10 shows the T_s overall indicator used in Russia for assessing reliability of aircraft and calculated as mean time between failures and faults caused by the shortcomings at the design and manufacture stages. The values of this indicator for the Ka-32A11BC helicopters (T_s = 51 h) and the Ka-32T helicopter (T_s = 69 h) do not differ too much one from another.

On the indenture level of the helicopter components, the conclusion is different. Regarding the systems in which elements based on mechanical operating principles prevail, namely, the airframe, the rotor system, and the powerplant, the indicators for the Ka-32A11BC helicopter are within 0.25–0.5·T_s for the Ka-32T and Ka-32S helicopters. In addition to the loads which characterize logging, the above systems of the helicopters in Canada were influenced by the large flying time accumulated in these operations. The result were the fretting of the surfaces of fuel tanks, wearing of electric motor brushes of the fuel pump, tire tread wear, abrasion of bolts and bushings in small-displacement links. The effect of logging was particularly strong on the T_{ds} indicator expressing the mean time between unscheduled removals of the model TV3-117VMA engine, the rotor hubs and blades, and the VR-252 gearbox (Fig. 11). For the failures of the gearbox characterizing the level of the transmitted torque (fracture of parts accompanied by the contamination of the oil with chips), the difference between the values of the T_{ds} indicator is especially large. For the model Ka-32A11BC helicopters in Canada, 12 such failures cased 10 unscheduled removals of the gearbox; whereas in Korea, there were only 2 unscheduled removals of the gearbox prompted by the appearance of chips in the oil. The other failures were caused by distinct manufacturing defects, such as leaking connections, imprecise adjustment of the oil pressure, and other shortcomings.

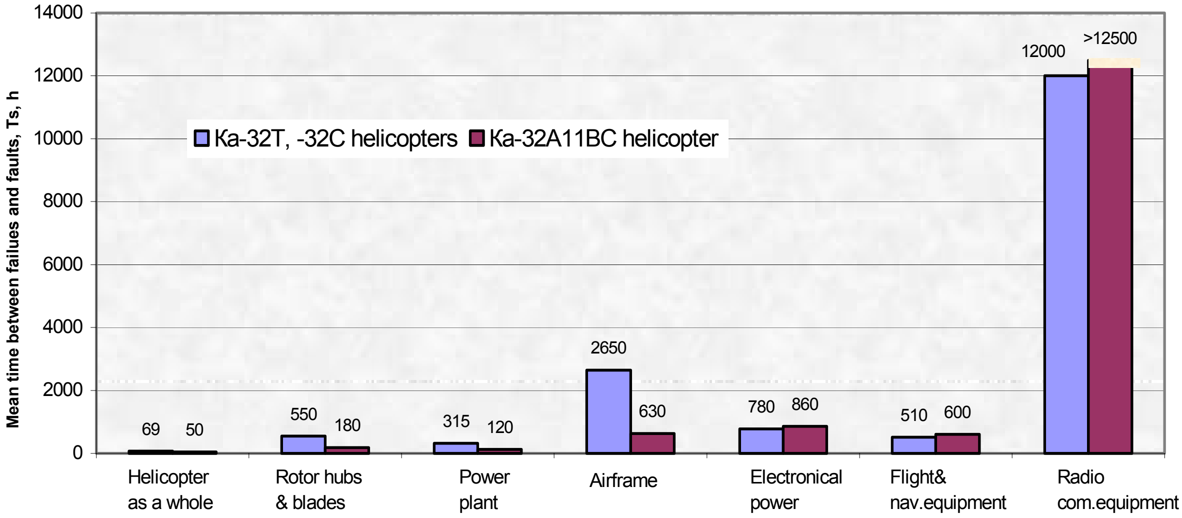

FIG. 10 MEAN TIME BETWEEN FAILURES AND FAULTS, T_S, FOR EACH MODEL KA-32A11BC AND KA-32T (-32S) HELICOPTER AS A WHOLE AND FOR THEIR SYSTEMS

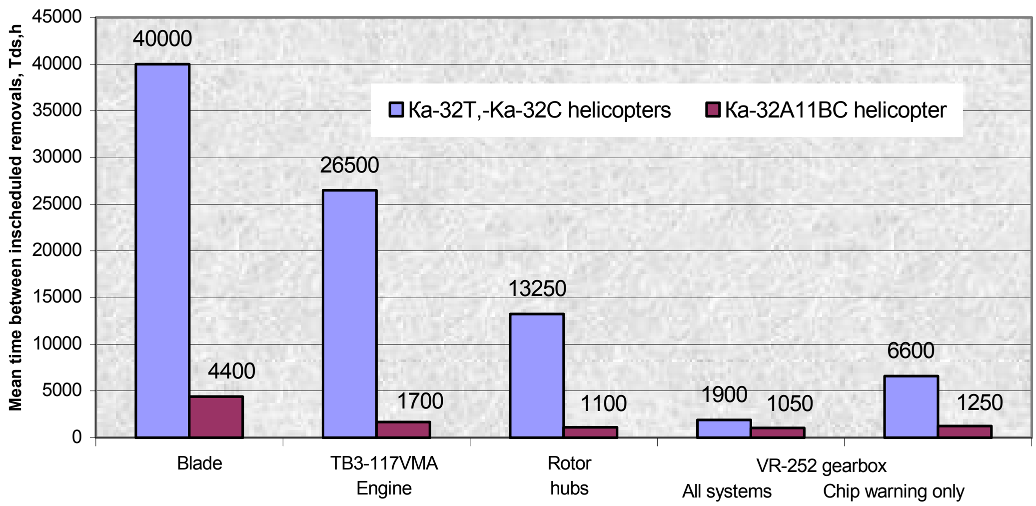

FIG. 11 MEAN TIME BETWEEN UNSCHEDULED REMOVALS, T_{DS}, FOR THE SYSTEMS OF THE MODEL KA-32A11BC AND KA-32T (-32S) HELICOPTERS

The electrical equipment of both these groups of helicopters had virtually the same reliability, although the failure modes were different. In Korea, failures of the warning channels were prominent, whereas in Canada the floodlights failed often.

Reliability of radio communication equipment of the Ka-32T and Ka-32S helicopters was low in comparison with such systems in the Ka-32A11BC helicopters. This was the result of the small annual utilization of the helicopters in Korea former aircraft. It should be pointed out also that in Canada the pilots use transceiver manufactured in the United States.

In January 2001, the technical condition of the C-FIGR and C-GKHL helicopters was investigated. By then, the flying time of these aircraft was 5375 and 6472 h, respectively. The investigation permitted to operate the model Ka-32A11BC helicopters on the basis of the on-condition maintenance strategy, even in the extreme conditions of logging, without subjecting these aircraft to a large-scale restoration. No structural failure was detected during the investigation. All of the detected faults, namely, damaged soft protecting covers, dented tubing, torn grounding connections, loosened fasteners, partial absence of paint, and other defects or faulty items are easily repairable or replaceable in the field.

Economic Aspect

The VIH Logging schedules the helicopter operations in shifts. Two flight crews and two ground crews are assigned to each helicopter. There are two members per crews—two pilots and two technicians. The guarantee team comprising three specialists from the Kamov Company and one specialist from the engine manufacturer supports the serviceability of the helicopters.

According to our estimate, the annual wage bill of the maintenance personnel of the three helicopters is US$ 1 110 000. The costs of the insurance and the hangar storage add US$ 200 000 per helicopter annually.

The direct operating costs of the model Ka-32A11BC helicopter are determined by the expenditures for the replacement items (US$ 1000 per flying hour) and the fuel costs (US$ 500 per flying hour, based on the fuel consumption of 860 l/h and the price of USC 58 per liter of grade Jet A fuel).

The relationship between the total costs per flying hour and the annual utilization is shown in Fig. 12. The increase in the annual utilization from 1000 to 2000 h reduced the costs by US$ 850 per flying hour. At the same time, the costs for hauling the timber were reduced to US$ 30 per ton.

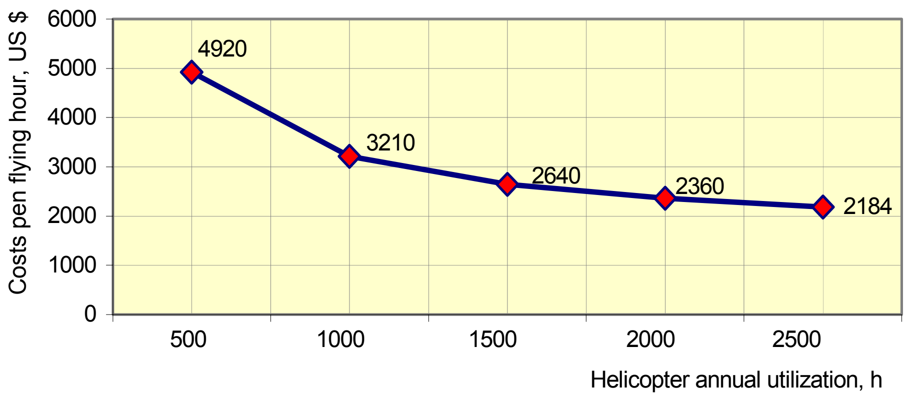

FIG. 12 COSTS PER FLYING HOUR AS A FUNCTION OF THE ANNUAL UTILIZATION

Conclusion

The four-years' experience with the Ka-32A11BC helicopters in Canada showed that apart from being good to fly the Kamov-built rotorcraft were efficient to be used for logging. The Company proved to be a reliably partner who ensured the intensive operations of the helicopters thousands of miles away from the manufacturers of the systems and components.

The near-to-extreme operating conditions caused several incidents which required quick corrective measures to be taken for sustaining continued airworthiness. The elimination of the detected shortcomings in the design enhanced the technological level and the competitiveness of the model Ka-32A11BC helicopters.