MINISTRY OF TRANSPORT, CONSTRUCTION AND REGIONAL DEVELOPMENT OF THE SLOVAK REPUBLIC

Aviation and Maritime Investigation Authority
Námestie slobody 6, P.O.BOX 100, 810 05 Bratislava 15

Reg. No.: SKA2012012

F I N A L R E P O R T

on investigation of accident

of helicopter type **Mi-8T**

Registration No. **OM-TMT**

Date: 03.08.2012

Place: Airport Poprad / LZTT

The investigation of occurrence has been conducted pursuant to Art. 18 of the Act No. 143/1998 on Civil Aviation (Civil Aviation Act) and on Amendment of Certain Acts and in accordance with the Regulation (EU) No. 996/2010 of the European Parliament and of the Council on investigation and prevention of civil aviation accidents and incidents, governing the investigation of civil aviation accidents and incidents.

The final report is issued in accordance with the Regulation L 13 that is the application of the provisions of ANNEX 13 Aircraft Accident and Incident Investigation to the Convention on International Civil Aviation.

The exclusive aim of investigation is to establish causes of accident, incident and to prevent their occurrence, but not to refer to any fault or liability of persons.

This final report, its individual parts or other documents related to the investigation of occurrence in question have an informative character and can only be used as recommendation for the implementation of measures to prevent occurrence of other accidents and incidents with similar causes.

A. INTRODUCTION

Operator/Owner:	TECH-MONT Helicopter company, s.r.o.
Type of operation:	aviation operations
Type of helicopter:	Mi-8T
Registration No:	OM-TMT

Take-off site:	Popradské pleso
Flight phase:	hover landing
Place of accident:	LZTT
Date and time of accident:	03.08.2012, 17:30

Note: All time data in this report are stated in the UTC time.

B. INFORMATIVE SUMMARY

On 3 August 2012 the crew of helicopter Mi-8T, registration No. OM-TMT, was making air charter work – transport of underslung load from the deposit area at the lake Popradské pleso to the chalet under the mountain Rysy.

On the return flight from the building site of the chalet under the mountain Rysy, during downward flight, the loose steel cable used for transport of load got into the anti-torque rotor. Its winding on the rotor head and subsequent rupture caused damage to blades of anti-torque rotor, which allowed, in spite of lower efficiency, the return of the helicopter by downward flight at optimal speed to the airport LZTT. A part of the transport cable cut off fell on the ground under the helicopter.

The helicopter captain decided to land at the airport LZTT. During the landing manoeuvre the helicopter became unstable and started to rotate on its vertical axis with subsequent control breakdown just before the contact with the ground. The blades of the main rotor ("MR") come into contact with the ground and got destroyed. After the termination of rotation the helicopter remained standing, inclined to the right side.

The crew left the helicopter without help with minor scratches and was transported to the hospital without serious injuries.

The commission composed from the following persons was appointed for investigation of the occurrence:

Ing. Igor BENEK
Ing. Zdeno BIELIK

The report is issued by:
Aviation and Maritime Investigation Authority
of the Ministry of Transport, Construction and Regional Development
of the Slovak Republic

C. MAIN PART OF REPORT

1. FACTUAL INFORMATION
2. ANALYSES
3. CONCLUSIONS
4. SAFETY RECOMMENDATIONS

1. FACTUAL INFORMATION

1.1 History of the flight

The crew of the helicopter was transporting underslung load from the deposit area at the lake Popradské pleso to the challet under the mountain Rysy. After disconnection of the fifth load at the challet under the mountain Rysy the crew set forth on downward flight with empty transport steel cable to the deposit area near the lake Popradské pleso with the intention to undersling and transport another load.

In the middle of this route the flight engineer noticed spontaneous swing of steel cable attached to the helicopter hook (which hanged loose under the helicopter during the flight).

Subsequently the steel cable got into the anti-torque rotor, wound up on the rotor head and broke, which caused damage to blades of anti-torque rotor and thus decline of its efficiency.

All crew members registered a hard blow followed by swing of the helicopter. After stabilization of the flight the helicopter captain opted for landing with ground roll to the airport LZTT. However, before landing he changed mind and decided for traditional helicopter hover landing.

The captain made the preparation and approach to the grass runway ("RWY") 07.

The landing approach went smoothly. Just above the ground the helicopter started turning left, twirl in a spiral and rotate on its vertical axis. Then it became uncontrollable and hit the ground. Upon impact the blades of MR came into contact with the ground and got broken. During the last light phase, just before the contact, the helicopter tail with anti-torque rotor as well as some transmission parts broke up.

After the termination of rotation the helicopter remained standing, inclined to the right side.

Daytime: day

Flight rules: VFR

1.2 Injuries to persons

Injury	Crew	Passengers	Other persons
Fatal	-	-	-
Serious	-	-	-
Minor	-	-	-
None	3	-	

1.3 Damage to helicopter

The helicopter was destroyed in the accident.

1.4 Other damages

No circumstances with potential claims for compensation of other damage toward a third party were notified to the Aviation and Maritime Investigation Authority.

1.5 Personnel information

<u>Pilot in command:</u>

Citizen of the Slovak Republic, aged of 47 years,

holder of Airline Transport Pilot Licence (Helicopter), ATPL(H) No. SK 08040337, issued by the Civil Aviation Authority of the Slovak Republic on 22.12.2004 with validity until 03.05.2017.

Medical certificate:

of 1st class with marked validity until 26.01.2013,
of 2nd class with marked validity until 26.07.2014.

<u>Flight experience:</u>

Total flight hours:	4044 h 25 min
For the last 90 days:	92 h 55 min
For the last 30 days:	46 h 30 min
On the day of air accident:	2 h 55 min

First officer - navigator:

Citizen of the Czech Republic, aged of 61 years,

holder of the Commercial Pilot Licence (Helicopter), CPL(H) No. CZ/001228538, issued by the Civil Aviation Authority of the Czech Republic on 1 February 1999 with marked validity until 28.04.2014.

Medical certificate of 1st class with marked validity until 27.01.2013.

Flight experience:

Total flight hours:	3626 h 50 min
For the last 90 days:	57 h 15 min
For the last 30 days:	18 h 35 min
On the day of air accident:	2 h 55 min

Flight engineer:

Citizen of the Slovak Republic, aged of 43 years,

holder of the flight engineer´s licence No. 10980023, issued by the Civil Aviation Authority of the Slovak Republic on 9 February 1998 with validity until 22.05.2013.

Medical certificate:

of 1st class with marked validity until 23.05.2013,
of 2nd class with marked validity until 23.05.2014.

Flight experience:

Total flight hours:	4 656 h

1.6 Information about helicopter

Airframe:

Type	MI-8T
Registration No.:	OM -TMT
Serial number:	98308361
Manufacturer:	MIL MOSCOV, HELICOPTER PLANT

The certificate of airworthiness No. 0764, issued by the Civil Aviation Authority of the Slovak Republic, valid until 15.04.2013.

Third-party insurance: Allianz Slovenská poisťovňa, certificate No. 411014360.

1.7 Meteorological situation

Cloudiness: 3-4/8 at altitude of 5300 ft, 5-7/8 with bottom baseline 8 000 ft, temperature of 21°C, visibility above 10 km, wind 250°/5 kt.

Meteorological situation in the area of Poprad – High Tatra

On 3 August 2012 weather in the High Tatra mountain was relatively stable, without significant changes of circulation. In the afternoon indistinct cold front went through the area of Tatra and manifested itself by wind gusts, storm precipitations and increase of cloudiness.

METAR reports of 3 August 2012 (15:00-18:00) LZTT

METAR LZTT 031500Z 25004KT 220V280 9999 FEW060 24/16 Q1016 NOSIG=

METAR LZTT 031530Z VRB01KT 9999 FEW060 24/17 Q1015 NOSIG=

METAR LZTT 031600Z 00000KT 9999 FEW053TCU 25/16 Q1015 NOSIG=

METAR LZTT 031630Z 05002KT 9999 FEW053 23/18 Q1015=

METAR LZTT 031700Z 27003KT 9999 SCT053 22/18 Q1016=

METAR LZTT 031730Z 25005KT 9999 SHRA SCT053 BKN080 21/16 Q1016=

METAR LZTT 031800Z 27009KT 9999 TSRA SCT050 CB SCT060 BKN080 21/15 Q1017=

METAR LZTT 031830Z VRB06KT 9999 VCTS-SHRA SCT048CB SCT060 BKN080 20/15 Q1017 RETS=

The lapse rate of air was labile, i.e. the heated ground air needed to reach the level of free convection, which was at pressure level of 758.6 hPa (approx. 2 200 m), using some other mechanism in order to be able to rise spontaneously rise and form heap clouds. In a hilly terrain this mechanism could have been the anabatic ascent of overheated ground air layer along the sunlit bedrock of the Mengusovska valley. This local circulation, also called valley hot wind, has a daily period of change and after the sunset changes to catabatic cold mountain downhill wind. This change of wind direction does not occur by leap, but gradually depending on how the valley is shaded. At the time of the incident the west slope of the Mengusovska valley was already shaded and radiationally cooled, while the east slope remained sunlit and probably further produced upward air current. This air current could easily reach the level of free convection and continue to rise. On the west side of the valley the air cooling down started to descend in the valley and was gradually replaced by air aspirated from higher levels, which generated downward currents over the west valley side. This circulation picture is chaotic, especially in the area of contact of upward and downward currents, with occurrence of vortexes of different dimensions and intensities. On the critical day the convective available potential energy (CAPE) was 731.9 J/kg, Bulk Richardson number (BRCH) showing the intensity of thermic turbulence and wind shear was 72.83. These values indicate a low intensity of development of storms and thermic turbulence. However, it must be noted that these indices are modelled for free air and have lower representativeness in conditions of intensive friction, as is the case in hilly terrain.

CAPE – convective available potential energy measures air instability and on 3 August 2012 its value was 731.9 $J.kg^{-1}$, which represents weak activity. In our latitudes in summer CAPE >1000 $J.kg^{-1}$ in storm conditions.

BRCH – Bulk Richardson number is a criterion of thermodynamic air instability. On the critical day its value was 72.83. The **smaller** is the number, the stronger is the turbulence. Weak turbulence starts at BRCH < 0.5. The value recorded for the date of 3 August 2012 indicates stable atmosphere.

1.8 Aids to navigation

Not applicable.

1.9 Communications

The helicopter was equipped by a board radio station enabling two-way communication with all air stations at every moment of the flight.

1.10 Aerodrome information

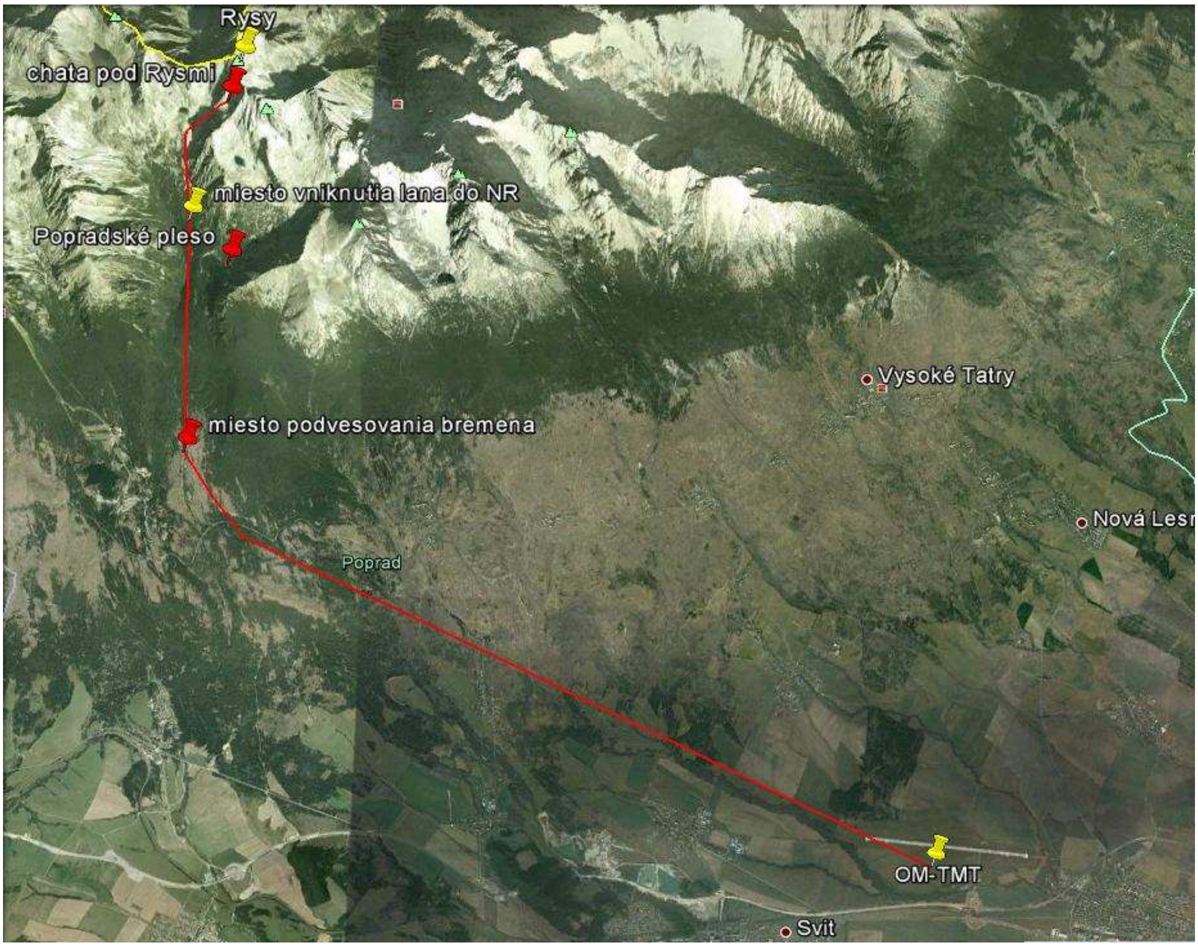
Not applicable.

1.11 Flight recorders and other recorders

The helicopter was not equipped by flight data recorder or other recording devices.

1.12 Wreckage and impact information

The place of accident is situated on RWY 07 of airport LZTT and is described by the coordinates N 49°04´ 13.9´´, E 020°14´ 17.6´´


Rysy
chata pod Rysmi
miesto vniknutia lana do NR
Popradské pleso
Vysoké Tatry
miesto podvesovania bremena
Nová Lesn
Poprad
OM-TMT
Svit


OM-TMT
Poprad-Tatry
Svit

1.13 **Medical and pathological information**

Not applicable.

1.14 **Fire**

No fire broke out.

1.15 **Survival aspects**

The search and rescue operations using SAR means were not required.

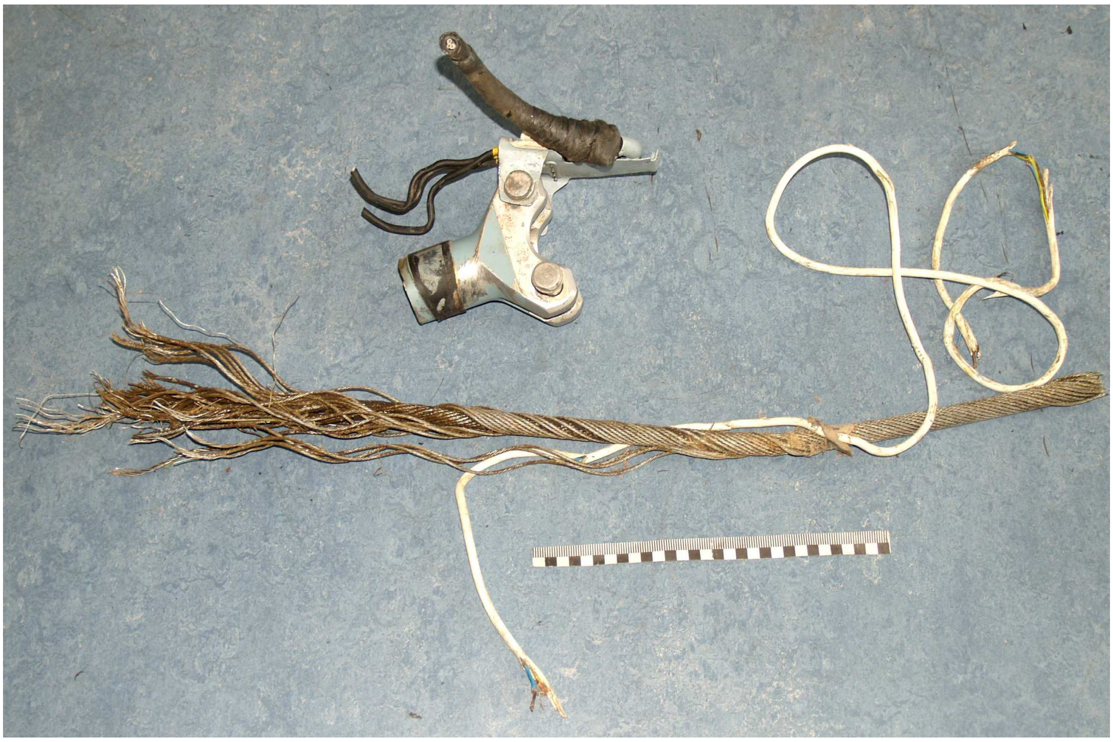
1.16 **Tests and research**

Two material traces were submitted for examination:

- a part of anti-torque propeller blade support hinge
- a part of damaged steel cable

The examination detected that the submitted steel cable was damaged by unauthorized or improper transverse loading (contact with foreign body). The design of cable (regular lay (and diameter of wires) corresponded with grooves and imprints on the surface of submitted part of the anti-torque propeller blade hinge.

In view of the character of examined grooves and imprints and damage to the cable, and practical impossibility of contact of the compensating propeller with other steel cable it can be assumed that the traces (surface grooves) on the submitted part of the anti-torque propeller blade hinge were left by the examined cable.



1.17 Organizational and management information

The flight of the helicopter was made as a part of performance of aerial work – transport of material from the deposit area near the railway station Popradské pleso to the chalet under the mountain Rysy.

The helicopter operator is a company that holds valid licence for performance of aerial work No. SK002 issued by the Civil Aviation Authority of SR.

1.18 Additional information

The flight was made with free underslung transport cable with total length of 28 m in the following configuration:

steel cable Hercules Ø 18 mm with length of 20 m;
two nylon strips, each with length of 4 m;
two canvas strips ended by steel suspension hooks, each with length of 2 m;
hemp cable for guidance of load to the place with length of 2 m.

1.19 **Useful or effective investigation techniques**

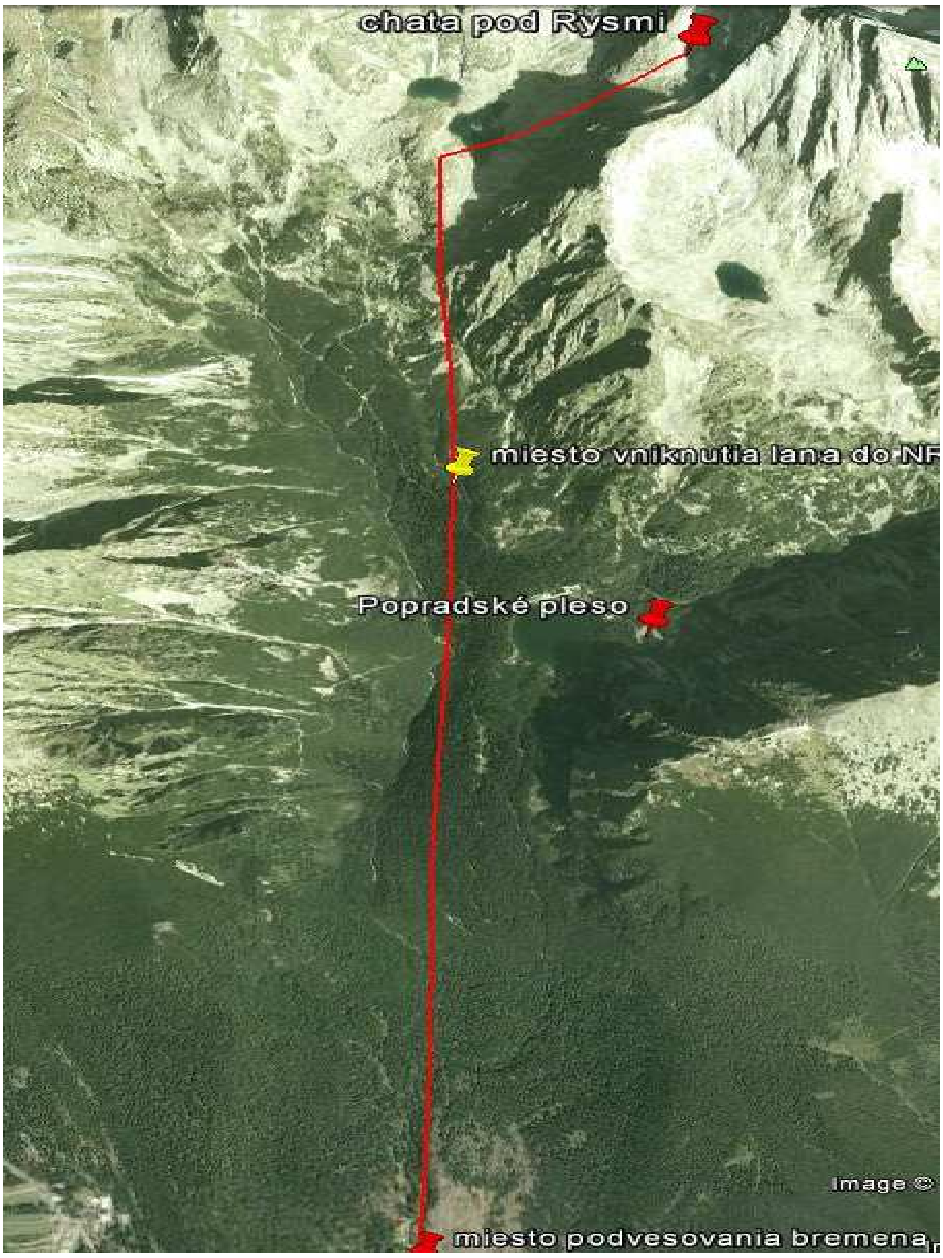
Standard investigation methods were used.

2. ANALYSIS

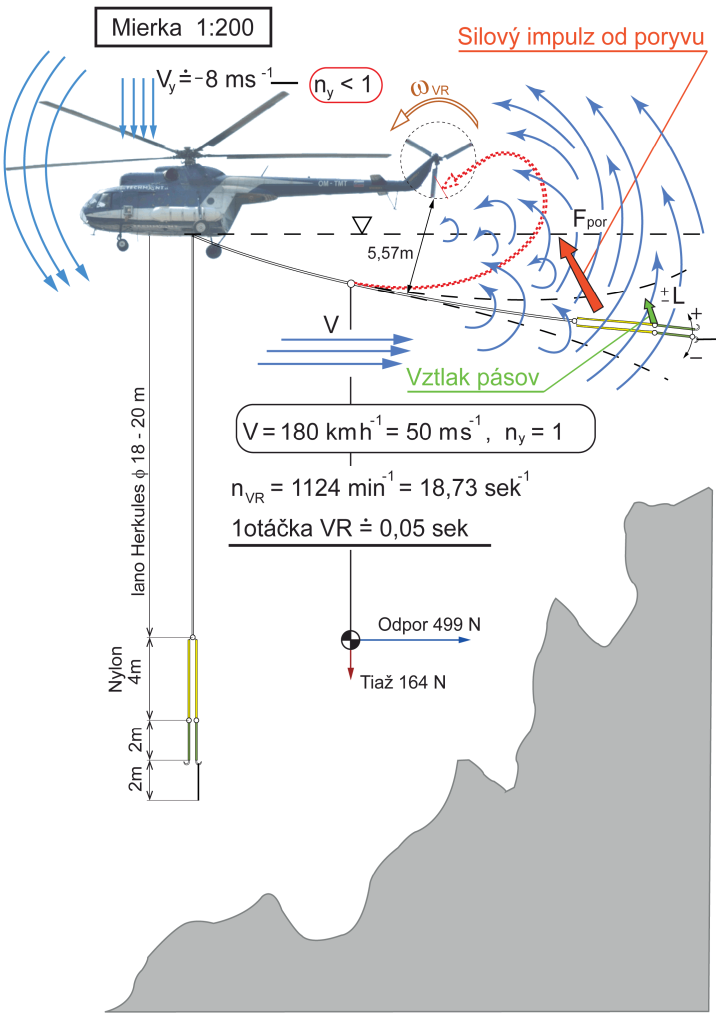
2.1 First phase of flight of helicopter – section from the challet under the mountain Rysy to the point of collision of the transport cable with anti-torque rotor

Helicopter Mi-8T was not equipped by flight data recorder, so the analysis of the critical flight relies, as regards its parameters, on the statement of the flight crew.

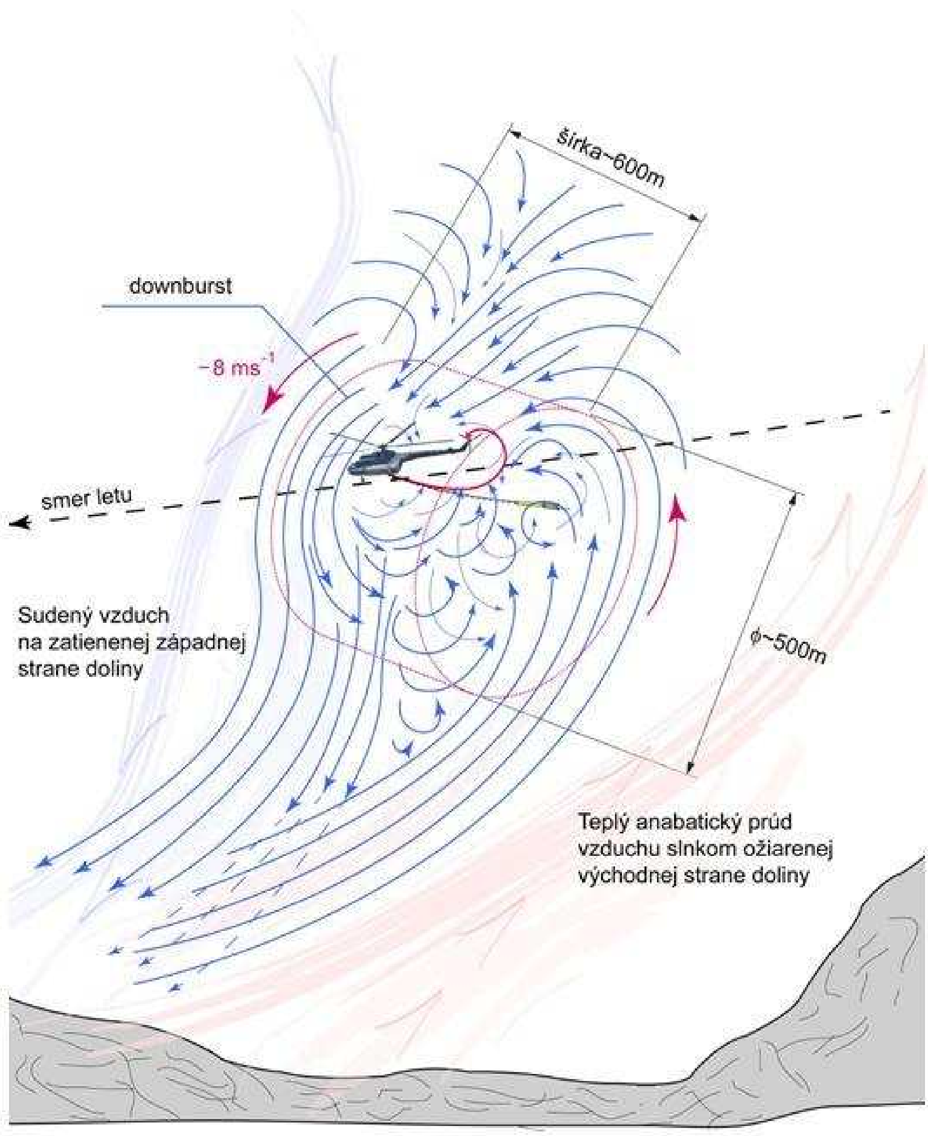
After discharge of load in the area of the chalet under the mountain Rysy at an altitude of 2 250 m, in good local meteorological conditions (wind 3 – 4 $m.s^{-1}$, visibility 10 km), short after five o´clock in the afternoon, the pilot started the downward flight along the west side of the Mengusovská valley.



The flight proceeded with free underslung transport cable



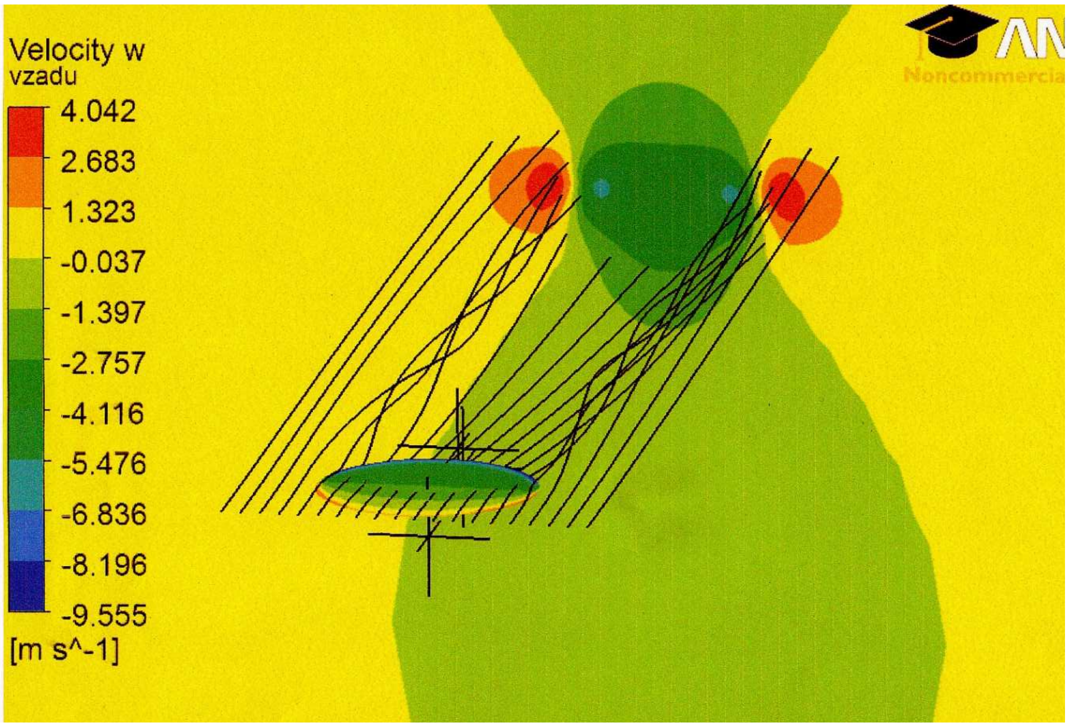
Estimated physical model of atmospheric processes which were the primary factor of the accident of the helicopter



Local meteorological situation in the upper part of the Mengusovská valley under the lakes Žabie plesá and its accidental dynamic development are typical for valley, where orographic and heat effects are in mutual contradiction at sudden change of circulation from a sunlit to a shaded area. The heated air gets into convection, which is thermal non-homogeneity in the form of rising air bubbles.

The trigger of convection at ground levels is the thermal gradient larger than 4.2° per km, occurring at fast overheating, in this case of the bedrock (beginning of August was characterized by temperatures around 30℃), which initiates the rising air bubble, bringing it up to the level of free convection (LFC). At the critical time, according to the enclosed thermodynamic chart, the value of LFC, where air bubble temperature is higher than the ambient temperature, was achieved at pressure level of 759 hPa, i. e. at an altitude of 2100 m. Upon contact of the hot downward anabatic circulation along the sunlit east side of the Mengusovská valley and the descending cooled catabatic circulation along the shaded west side of the valley, the air mass starts to rotate. In the end of the valley, in case of change of direction, the mechanism of cold air downburst is manifested by acceleration of downward circulation with ambient air induction to the emptied vacated area.

This rotating air mass (with estimated diameter of 500 m and width of 600 m) with approximate weight of 150 tonnes would reach, at temperature difference of 10℃ between the sunlit and shaded side of the valley, acceleration of up to 0.2 $m.s^{-1}$, which gives estimated speed of vortex motion around 8$m.s^{-1}$ (according to an idealized calculation model, which only takes into account the temperature difference, although other effects are manifested in the practice). The interaction of the gradient of acceleration of partial internal circulations of contemplated air mass with disturbances of vertical pressure gradient, wind shear, ruggedness of landscape and turbulences generated by work of MR can significantly increase the intensity of turbulent air rotation and its momentum with large energy content.



Collision of transport cable with anti-torque rotor of helicopter

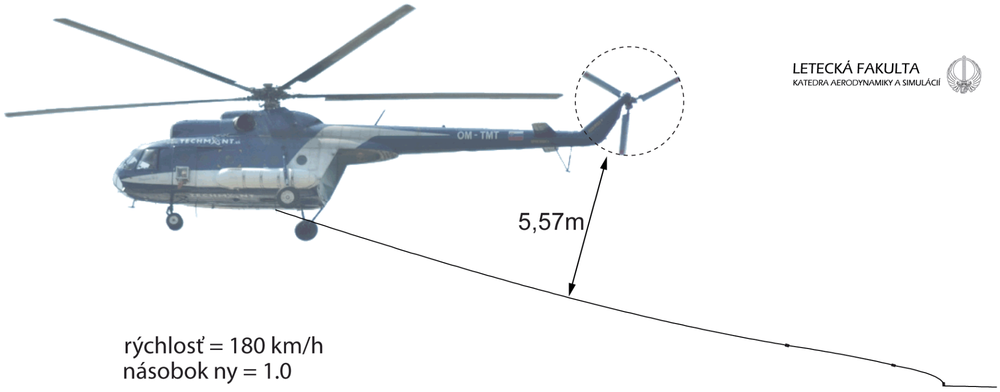
The entry of the helicopter in the descending part of rotating air mass, falling with a speed of 8 $m.s^{-1}$ in the area of the lakes Žabie plesá, was manifested by sudden movement of helicopter with probable decrease of the load factor to a zero-near value ($n_y \approx 0.2$). Subsequently, the flight speed spontaneously increased from 180 $km.h^{-1}$ to 200 - 210 $km.h^{-1}$. The pilot with the highest probability subconsciously reacted by pulling on the cyclic pitch lever to correct the increased flight speed. The common denominator of these factors and its consequence was mutual approach of the transport cable and the plane of rotation of the anti-torque rotor. This occurred for the following reasons:

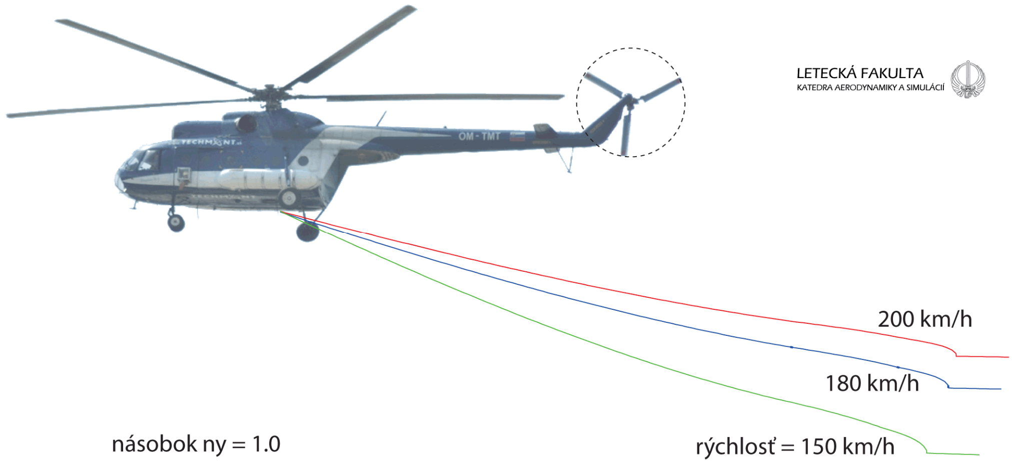
a) An increase of the flight speed of helicopter after entry in the descending wind gust causes a rise in aerodynamic resistance of underslung load. A larger pull of resistance on the cable carrying the load will be manifested by rise of its position, i.e. approach to the anti-torque rotor.

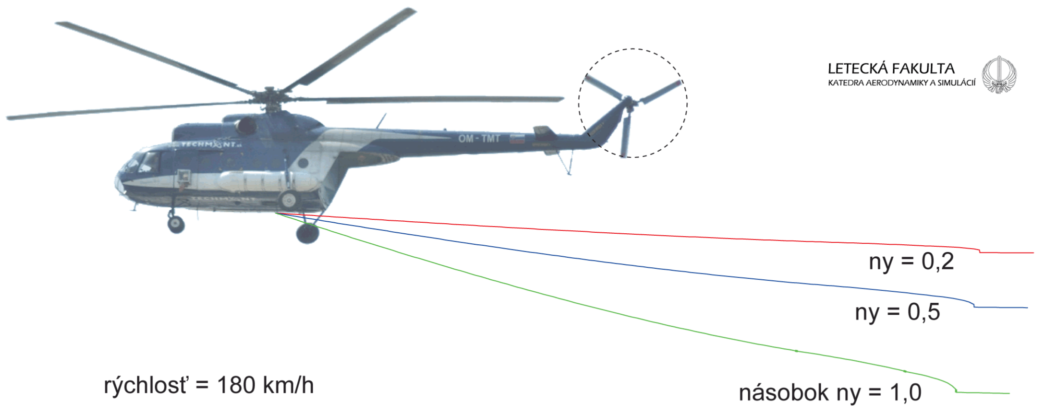
b) A decrease of the load factor in case of sudden movement of the helicopter will be manifested by approach of the anti-torque rotor to the raised level of the end section of the cable carrying the load.

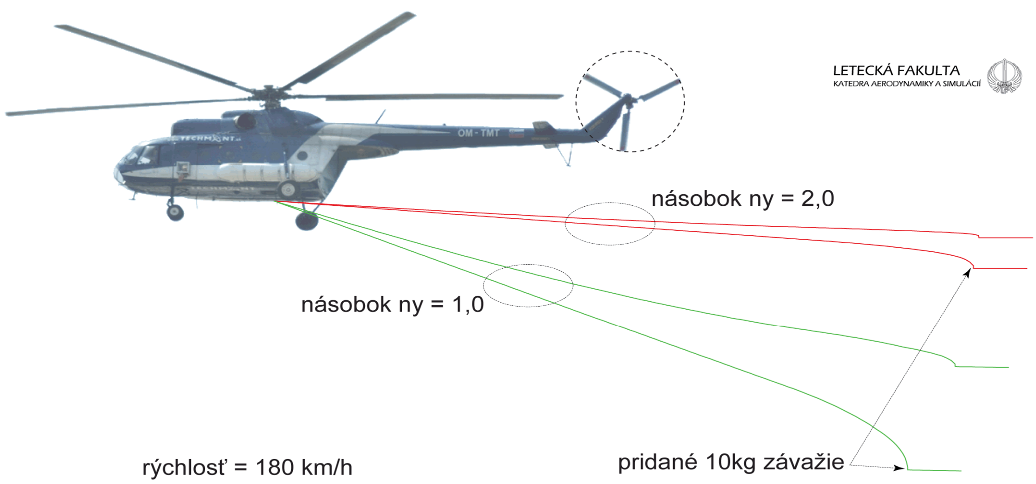
c) In the effort to reduce the spontaneous increase in speed caused by the wind gust the pilot probably subconsciously pulled on the cyclic pitch lever (in this case the proper reaction would be to lift the collective pitch control lever) and thus brought the helicopter to the positive pitch angle. The tail boom with anti-torque rotor sank and thus even more approached the raised level of the oscillating end cable section.

The positions of cable to the helicopter for different flights are shown by the computer simulation.









It must be noted that the described process of dynamic transformations is, timewise and by its location, a split-second random event, often without possibility for the crew to affect its result. Even long years of experiences are not a guarantee of safe flight in mountain conditions. Each flight in mountains is different in a way and the risk of instability o fair masses often does not indicate its presence (e.g. by formation of clouds). In this case the entry of the helicopter in the whirlwind, characterized by complex internal structure of turbulence with large kinetic energy, together with response of the helicopter and reaction of the pilot, were the cause of penetration of the transport cable into the working area of the anti-torque rotor.

Besides the above factors, the initiating impulse for penetration of the cable into the anti-torque rotor was probably the bank and drift of the helicopter. The asymmetric circulation of rotating air mass caused an vigorous sideways motion of the helicopter, which was the impulse for a lateral swing of the cable, in particular its very flexible nylon section, together with canvas strips situated in the core of the descending section of the turbulent vortex. The application of inertial forces of cable masses and aerodynamic forces to flexible nylon strips swept by the whirlwind caused that the end section of the cable rolled up in a loop and at that moment a relatively weak dynamic impulse was enough for it to swing up where it was probably sucked in by underpressure on the suction side of the anti-torque rotor and caught by rotor blades.

2.2 Flight phase of helicopter after penetration of the cable into the anti-torque rotor

In nominal operating regime of the power unit the anti-torque rotor has roration speed of 1124 rpm^{-1}, which is 18.73 revolutions per second. After the contact of the end flexible hemp section of the transport cable with the plane of rotation of the anti-torque rotor the cable started to quickly wind on the anti-torqueieho rotor head. At rotor speed of 18.73 revolutions per second, the winding of the cable section exceeding the length of helicopter (15.3 m) on the anti-torque rotor head with diameter ⌀ 280 mm, until stretching of the remaining cable section (12.7 m) attached to the suspension device in the helicopter body, took only 0.9 s! At that moment the seel cable dynamically stretched up to the ultimate tensile strenght broke at the bending point (tension concentrator), at the point of contact with the anti-torque rotor blade hinge.

After breakage a part of the loose end of broken cable, attached in the helicopter body, sprang back flexibly and wound on the right half of stabilizer, causing a severe damage to it.

The separated section of the cable (cca 15.3 m), wound on the anti-torque rotor head, started to unwind (against the direction of rotation of the rotor, but slower than in case of its winding on the rotor head) by application of progressively growing centrifugal force. By gradual unwinding of the cable the mass imbalance of anti-torque rotor increased and manifested itself by **intensive** oscillation of the helicopter in the longitudinal direction. (Mass imbalance of rotating body means a state when the main central inertia axis is not identical with the axis of its rotation – static imbalance).

Once unwound, the cable was tossed by centrifugal force and the amplitude of oscillation significantly declined. (During unwinding the cable probably must have flown between the MR blades several times without causing severe damage to them).

When leaving the area described by the anti-torque rotor, the end part of the suspension device with suspension hooks hit the nearest blade of anti-torque rotor and damaged it severely. By application of the centrifugal force the blade broke up at the point weakened by damage (honeycomb part of the blade end probably with weight of 5 kg).

The misalignment of the gravity center of the anti-torque rotor caused by partial breaking of the blade caused its new mass imbalance, which manifested itself by continuing, but less significant longitudinal oscillation of the helicopter. In the next seconds of flight a honecomb part of another, less damaged opposite blade broke up under the influence of centrifugal force, due to which the mass imbalance of anti-torque rotor and hence the level of vibrations of the helicopter decreased.

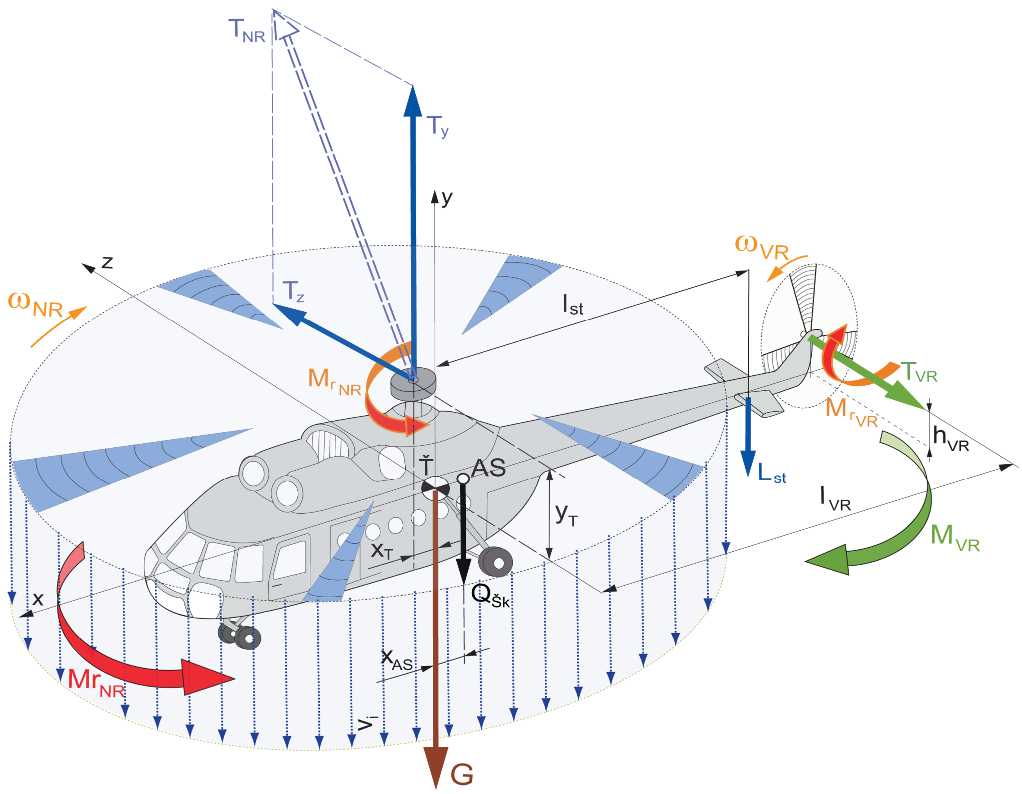
The loss of area of anti-torque rotor blades caused the decline in rotor efficiency, which however was sufficient for the **flight speed** (approx. 150 $km.h^{-1}$) and could be compensated by adjustment of larger rotor blade pitch using the right rudder pedal.

In this flight phase the pilot subjectively did not register any relevant warning signs indicating serious threat to flight safety.

2.3 Final flight phase

In view of the estimated damage to anti-torque rotor of unknown extent, which however allowed the flight control in the engine descent mode at a speed of 150 $km.h^{-1}$, the pilot decided to interrupt the work programme and to land at the airport LZTT.

He made the approach from the flight direction and opted for a traditional helicopter landing with deceleration of the flight speed up to the hover position in a height of 3 – 5 m and touch-down by vertical lowering on the grass surface near the concrete runway of the airport. The following picture shows forces and moments affecting the helicopter in the critical final flight phase, which normally ends with helicopter hovering at zero flight speed, under balanced stabilised conditions:



Basic conditions of stabilised helicopter hover:

1. $\mathbf{T_y = W}$: condition of constant hovering height
2. $\mathbf{T_z = T_{VR}}$: condition of zero lateral shift of helicopter
3. $\mathbf{T_x = 0}$: condition of zero shift in the longitudinal direction (axis x)
4. $\mathbf{M_{VR} = Mr_{PR}}$ condition of constant hovering direction

2.4 Analysis of causes of air accident in the final flight phase

The main cause of the accident, by which the landing of helicopter ended, is the non-fulfilment of the fourth condition of balance of moments around the vertical axis of helicopter, i.e. $\mathbf{M_{VR} = Mr_{PR}}$.

Chronology of physical principles during the flight:

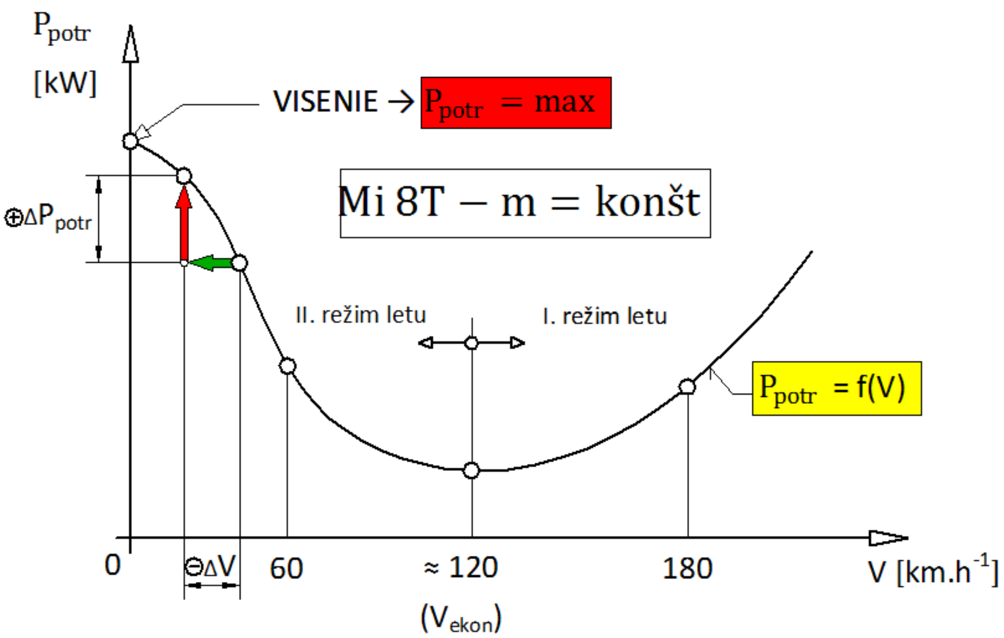
For a flight of helicopter at arbitrary speed, including the zero speed – hover, the following condition must be fulfilled: thrust $\mathbf{T_{PR}}$ developed by MR must be equal to the helicopter weight **W = m.g**, where **m** is its flight weight.

For development of thrust by MR as aerodynamic force that is generated by air flowing around MR blades at rotation of MR the exactly defined output $\mathbf{P_{potr}}$ delivered by the power unit is required, especially for overcoming of aerodynamic resistance of blades at rotation of MR ($\mathbf{n_{PR} = 192}$, i.e. 214 $m.s^{-1} \approx 770$ $km.h^{-1}$), which grows with the second power of the peripheral velocity.

The power unit of helicopter Mi-8T consists of two shaft-turbine engines TV2-117AG, each with output of 1104 kW. The value of required input P_{potr} depends on the first approach at flight mass **m** (in this case it is constant) and on the operating mode of PR, which is characterized by two types of flow-around:

a) axial flow-around mode – with hovering helicopter and similar modes – requires maximum required input $\mathbf{P_{potr}}$ at given flight mass

b) scewed flow-around mode – for flight speed approximately above 50 – 60 $km.h^{-1}$ – it is manifested, especially in the transition area at low speeds, by significant change of required input.



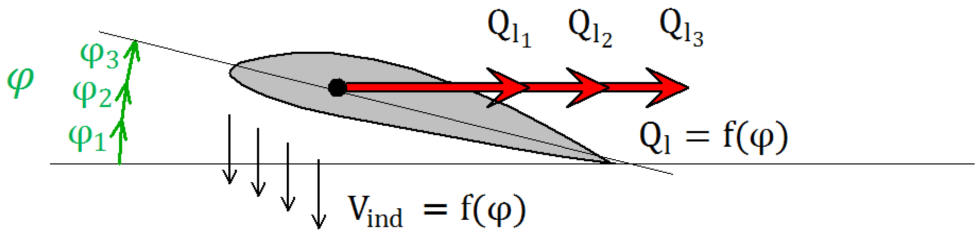
Besides the flight mass and flight speed, concrete values of required input depend on the flight height, air temperature and air humidity.

In the final phase of landing each helicopter decreasing the forward speed from the level of approximately 60 km.h^{-1} by transition to the scewed flow-around mode to the axial flow-around mode tends to significantly increase the vertical speed of descent.

The cause is the decline in thrust of PR, which is dependent on the flight speed $\mathbf{V_{flight}}$ and induced speed $\mathbf{V_{ind}}$, i. e. speed of air mass accelerated by rotor according to the relation (or simply according to the impulse theory):

$$T_{NR} = 2.\rho.V_{letu}.\,V_{ind}.S_{NR} = W \qquad \text{(N)}$$

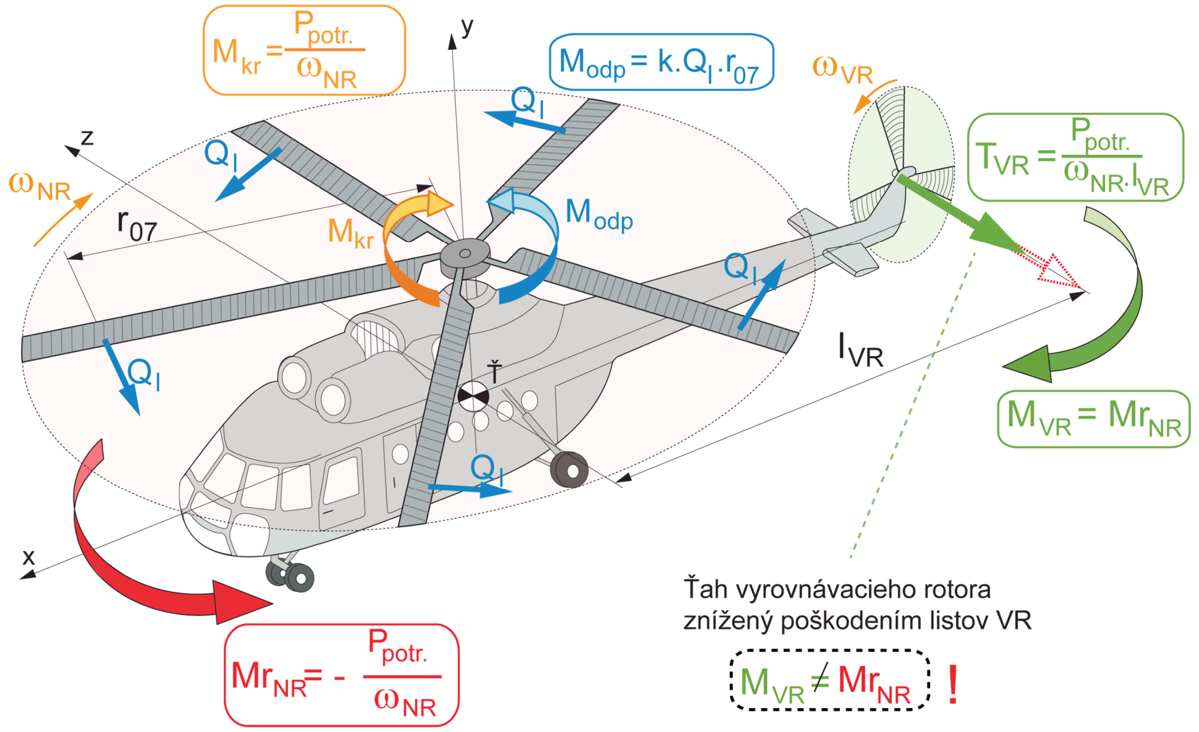
When decreasing the flight speed $\mathbf{V_{flight}}$, the pilot has to increase the induced speed $\mathbf{V_{ind}}$ of air mass accelerated by MR in order to maintain the required thrust of MR $\mathbf{T_{PR} = W}$ and the possibility of control with the aim to maintain a sufficiently low speed of vertical descent with approach to the ground (in the final phase approx. 0.2 m.s^{-1}). This process requires the increase of the angle of collective adjustment of MR blades φ .



At a larger angle of adjustment of MR blades the induced air speed under the rotor $\mathbf{V_{ind}}$ and hence the thrust of PR, which brakes the descent of the helicopter, increase. However, the aerodynamic resistance of blades $\mathbf{Q_l}$ and hence the moment of aerodynamic resistance of MR blades against rotation, which has the effort to brake the rotational speed of PR, increase as well.

For prevention of the decrease of MR speed and for achievement, at the increased angle of adjustment of MR blades φ , of the required thrust of MR by gradual increase of the induced speed $\mathbf{V_{ind}}$ it is necessary to introduce **higher** required input $\mathbf{P_{potr}}$ to the MR shaft.

The increase of required input of engines $\mathbf{P_{potr}}$ at constant rotational rate of MR $\boldsymbol{\omega_{PR}}$ (revolutions of PR) will result in the rise of torsional moment on MR shaft. It counteracts the moment of aerodynamic resistance of MR against rotation and maintains its constant speed and hence its thrust $\mathbf{T_{NR}}$ at the required level.



According to the law of action-reaction (Newton´s third law) the helicopter body is affected by a moment of the same size but with opposite orientation – reaction moment Mr_{NR}. This reaction moment acts through the MR shaft and the main gearbox and in case of right-rotating rotor tries to turn the helicopter body to the left. For prevention of the helicopter turning to the left it is necessary to counterbalance this reaction moment of MR by a moment with the same size and opposite orientation. This moment balance is ensured by thrust $\mathbf{T_{VR}}$ of anti-torque rotor, situated in the end of tail boom of the helicopter, on the arm $\mathbf{l_{VR}}$.

The pilot ensures the required thrust of anti-torque rotor $\mathbf{T_{VR}}$ by change of the angle of adjustment of its blades through actuation of rudder pedals depending to the flight mode.

The moment of anti-torque rotor $\mathbf{M_{VR}}$ counterbalances the reaction moment of MR Mr_{NR}, ensures the equilibrium of helicopter around its vertical axis and keeps the helicopter in chosen heading.

The aforesaid penetration of transport cable into anti-torque rotor during the flight and subsequent damage to its blades significantly changed the described mechanism of normal implementation of the final flight phase.

At relatively higher flight speed in the phase of landing approach (approx. 150 km.h^{-1}) the values of required input for flight, torsional moment for MR and corresponding reaction moment of MR were relatively small and thrust generated by damaged anti-torque rotor were sufficient for counterbalancing of the reaction moment. The pilot therefore did not notice the insidious situation during the flight.

The decrease of flight speed before landing below 60 km.h^{-1} and the explained requirement for significant growth of required engine input are directly related to the increase of the torsional moment on MR shaft and hence the reaction moment of PR, which tries to **turn the helicopter to the left**.

The pilot counterbalanced the growing reaction moment Mr_{NR} by increasing the thrust of anti-torque rotor $\mathbf{T_{VR}}$ and the angle of adjustment of its blades through actuation of the right rudder pedal and he counterbalanced the helicopter during the landing manoeuvre by pulling the cyclic pitch control lever to the right.

Just before the hover, the engine input, torsional moment on MR shaft and corresponding reaction moment $M_{r_{NR}}$ achieved values that fragments of blades of damaged anti-torque rotor were unable to counterbalance any more by their insufficient thrust in spite of full actuation of the rudder pedal by the pilot to the right.

Close the ground the disturbed balance of moments caused by dominance of the reaction moment $M_{r_{NR}}$ manifested itself by fast, spontaneous spinning of the helicopter to the left.

At that moment, this spontaneous uncontrollable rotation of helicopter around the vertical axis was worsened by effects of unbalanced lateral force of MR $\mathbf{T_Z}$ (when pilot tried to prevent the helicopter from undesirable lateral shift to the left from single thrust force $\mathbf{T_{VR}}$ of anti-torque rotor) and partially decelerated forward motion of the helicopter.

The result of this complicated disequilibrium of forces and moments affecting the helicopter in a low altitude and within short time interval (seconds) was left-handed spiral descent of the helicopter with right banking from the lateral force $\mathbf{T_Z}$ on PR. The progressively growing rotating rate of helicopter in left spiral ended (2 – 3 revolutions for 15 s) caused that right landing-gear wheel hit the ground and the helicopter turned on the right side.

Due to the contact of rotating MR blades with the ground the helicopter got destroyed. Besides total destruction of the helicopter, after the contact of already damaged blades of the anti-torque rotor with the ground the end part of tail boom with anti-torque rotor came apart from the helicopter body.

3. C O N C L U S I O N S / CAUSE OF ACCIDENT

3.1 Findings

- the crew members had valid qualifications for performance of the flight,
- the helicopter had valid documentation and did not show any faults before the air accident,
- the helicopter fulfilled the conditions of airworthiness before the critical flight,
- the helicopter was destroyed in the air accident.

3.2 Causes of air accidents:

- the entry of the helicopter in a massive vortex generated by convective activity in its descending part. The cummulation of the helicopter swing and the assymetric air circulation with regard to the lateral motion provoked by MR activated an impulse which at a speed of 180 $km.h^{-1}$ tossed the loose end of transport cable to the working area of anti-torque rotor;

- the pilot´s decision to make hover landing with damaged anti-torque rotor. This type of landing manoeuvre requires higher engine output and hence increased reaction moment, which the damaged anti-torque rotor was unable to counterbalance even by full actuation of the rudder pedal.

3.3 Secondary cause:

- performance of aerial work in difficult mountain terrain and specific weather conditions.

4. SAFETY RECOMMENDATIONS

On the basis of investigation of causes of the accident of

helicopter type **Mi-8T**
registration No. **OM-TMT**
date of accident: **03.08.2012**

we recommend the Civil Aviation Authority of SR to take the following measures:

to invite the aircraft operators performing this type of aerial work with use of similar aeronautical appliances:

1. to analyse the results of investigation of the air accident with aviation and technical personnel, focusing on specifics, limitations and risks of implementation of activity in hilly terrain in given location and season of the year,

2. for assurance of flight safety with unloaded long transport cable in mountains:

   - not to increase the flight speed above 150 $km.h^{-1}$,
   - to permanently load the end part of the suspension device by steel weight of 10 kg with cylindrical shape, which will ensure a lower position of the cable and slower motion of the end of suspension device during empty flight,
   - to consider the replacement of very flexible, 4 m long nylon end part of the suspension device,

3. to supplement the operating manual by recommendations set out in paragraph 2 for performance of aerial work for specific types of aeronautical appliances,

4. to take their own measures on the basis of investigation results.

Bratislava, 11.03.2013