24th EUROPEAN ROTORCRAFT FORUM
Marseilles, France -15th17th September 1998

Zbigniew Maciej Romicki
The IS-2 Helicopter Chief Design Engineer
The Institute of Aviation, Warsaw
Référence : TE09
Wiesław W. Łucjanek
Warsaw University of Technology,
Warsaw, Poland

Helicopter Research at the Institute of Aviation in Warsaw

Founded in 1926 in Warsaw, the Institute of Aviation plays the key role as the background area for the aircraft industry research and scientific work. The Institute services are working for the following factories: in Mielec (aircraft manufacturing), in Rzeszów (piston and turbine engines producers), and in Świdnik (helicopters). The Institute carries out some research and experimental work which results are offered to be applied by the Polish aviation industry in general.

At the moment, there are over 500 employees at the Institute, 220 of which are the research workers. The chief lines are as follows: Aerodynamics (sub- and supersonic wind tunnels), Aircraft Engines (designing, engine test houses testing), Structural Strength (calculations and static and dynamic testing of assemblies and complete objects), Equipment (instruments and systems designing and testing) and in-flight testing. We also carry on designing and assembly work; the majority of it is being monitored by the bodies which check if it is in accordance with the international aviation regulations (JAR and FAR mainly).

The Institute of Aviation helicopter history started in 1948 (that is much earlier than in many European countries) and yet, in 1953, the first Polish helicopter Gil-1 (pic. 1a) underwent its test flying. That was a piston engine propelled, two-rotor blade two-seater. Its rotor head, which was unconventional and modern for the time, had got a mass balance system for the rotor blades flapping and lagging compensation. In 1955-1959, a new small single-seat Trzmiel (pic. 1b) helicopter was designed; it was propelled by jet engines mounted on the blades tips. In 1960, another helicopter was created; it was a three-rotor blade, four-seat Żuk helicopter (pic. 1c). None of these were introduced into manufacturing and no other further work on new designs was carried out because in 1960, the Świdnik factory (basic for the Polish helicopter industry) started manufacturing of the Soviet licensed Mi-2 helicopter (8 000 were made altogether). At the moment, a light two-seat helicopter temporarily named IS-2 (pic.1d) is under construction at the Institute of Aviation. It is a piston engine propelled (Lycoming 180 HP), three rotor blade helicopter with a landing skid. It is based on a truss structure, the tail boom is a duraluminium torque box, the cockpit (wide, comfortable, good glazing), the fin and the rotor blades are composites. The helicopter is supported with a series of the research work. The work goes in the Institute designed and made testing stands. Most of the below mentioned research and stands have been constructed and modernised just for the IS-2 needs.

The Oscillating Blades testing

As we all know, almost every new helicopter has got newly designed or modified old aerodynamic profiles. At our Institute they are designed by the Numeric Calculations Section of the Aerodynamics Department. Then, their static characteristics are tested in a low velocity wind tunnels (up to 80 m/sec) and high velocity wind tunnels within the range of Ma=0.2-0.96.

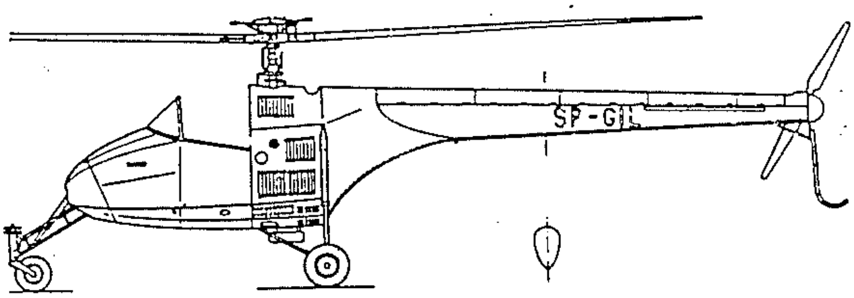

Fig. 1a. Helicopter SP-GIL, 1953, 33 hours of flight.

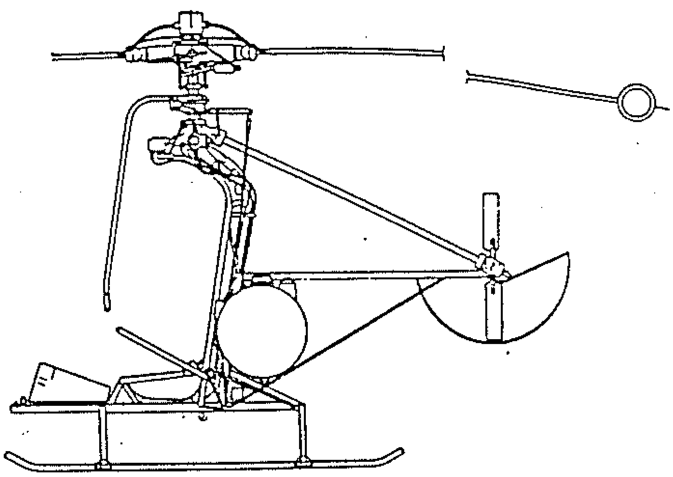

Fig.1b. Helicopter „TRZMIEL", 1955-59, two jet engines on the tip of blades.

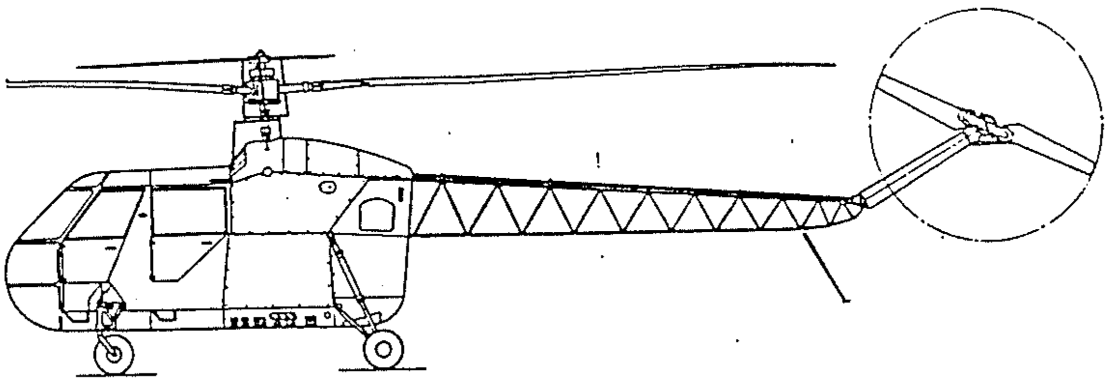

Fig. 1c. Helicopter BZ-4, „ZUK", 1960,

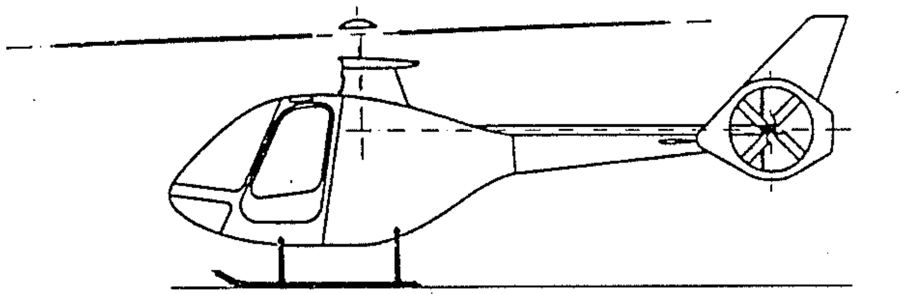

Fig. 1d. Helicopter IS-2, modern construction.

FIG.1 Helicopters from the INSTITUTE OF AVIATION, WARSAW, POLAND

Moreover, some profiles had their dynamic characteristics tested as well; they were the oscillating blade characteristics of the angle of attack close to flow separation. To perform the testing, we constructed a stand at which the profile (model a rectangular aeorfoil of the 0.2 m chord and 0.5m length) was forced to oscillate (kinematic forced). A medium angle of attack, amplitude and vibration frequency were set and we measured momentous pressure distribution noting phase lag between the measuring point and the pressure pick-up. The testing was performed in the , low turbulence wind tunnel at the velocity range of up to 100 m/sec. The sample results are presented in pic. 2, the tests results were published.

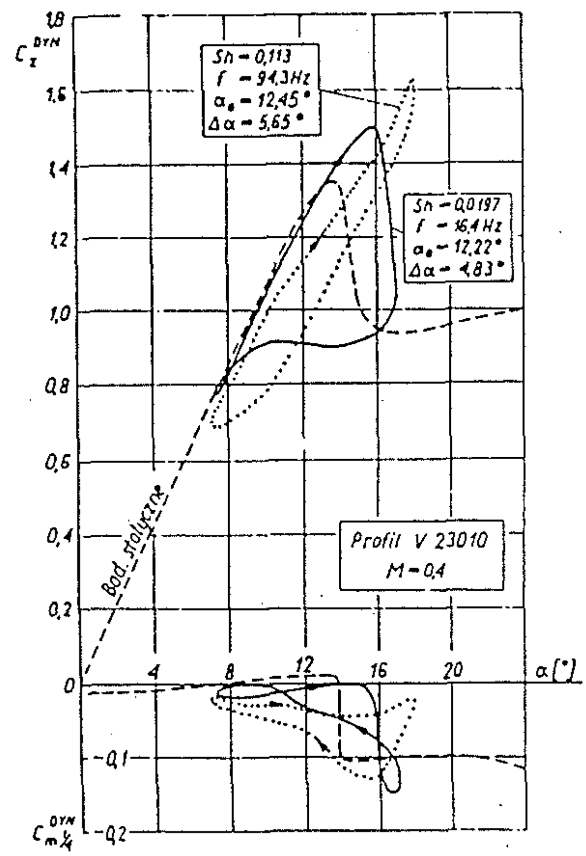

Fig. 2. Results of measurements of dynamic characteristic the V 23010 profile.

The Rotor Blade Tip Testing

The problems concerning rotor blade tip designing have been widely known thus we shall not discuss them here. Since we assumed that the IS-2 helicopter should produce relatively low amount of noise, it was necessary to fight the problem at the earliest stage possible. To this end, on one hand the blade tip velocity was lowered (up to 195 m./sec.) while on the other hand a research work was set up to design a tip flow which could move away shock stall. The research and testing has been being performed in the supersonic wind tunnel 0.6m x 0.6m chamber within the velocity range of up to 0.92 (the Mach number range for the tunnel is up to 3.2). The blade tip model is joined with the five strain gauge boundary balance; we use the flow visualisation methods (Schlieren), pressure distribution and/or the boundary layer measuring.

We do realise that such a research is two-dimensional in a sense, but it seems that the results may become the basic data for the relatively correct blade tip design.

The Rotor Model Testing

At the Institute of Aviation, the basic equipment for helicopter testing is the stand for rotor characteristics and rotor-fuselage interference testing. The stand (pic. 3) can be used in our wind tunnel of the 5m. in diameter testing space and max. velocity of 55 m./sec. The tested rotor diameter is of up to 2 m. and the rotor propelled power of 45 kW. There is no connection between the rotor, propeller system and controls and the helicopter fuselage although their positioning is stable and correct. The two independent testing systems are employed here: the first one – to control and testing of the helicopter rotor, and the second – to measure six components of force (extensometer) acting on a fuselage. Both systems are mounted on the same frame, thus enabling to make graduation and testing outside the wind tunnel and moving the whole stand into the wind tunnel as well. In the tunnel, the system makes it possible to change the pitch angle and the angle of glide.

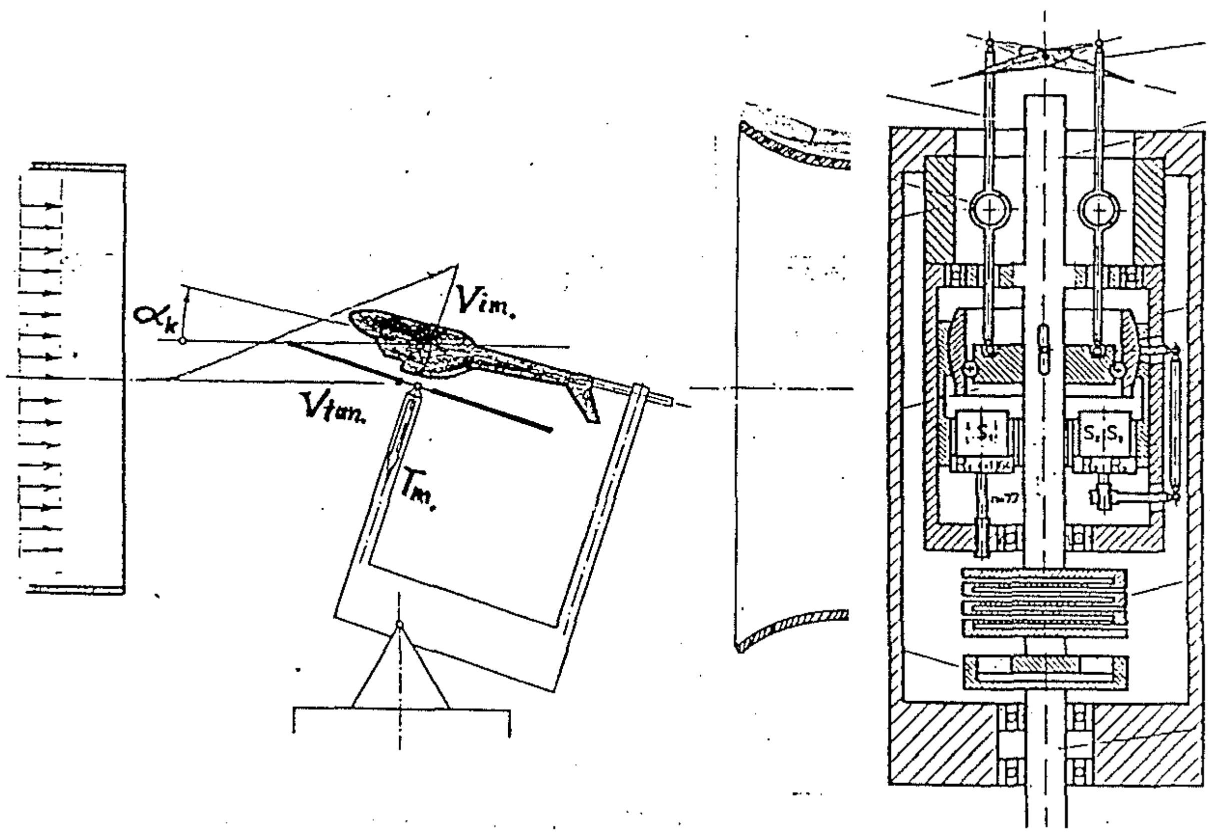

Fig. 3. Stand for rotor - fuselage interference measurements.
On the right side - control - testing unit.

The testing/controls head of the stand requires a separate description. It is the head which plays the role of a regular helicopter head with a swash plate. It can be used in the testing of two, three- or four-blade rotors, has a control system for the general and phase angles of blades, net torque testing system, rotor aerodynamic lift testing system and pushers forces testing systems. The general and phase angles are controlled by the miniature electric motors system; the whole unit is controlled from the testing room through the HP computer based system. In pic.4 we present the sample testing results for the W-3 'Sokół' helicopter.

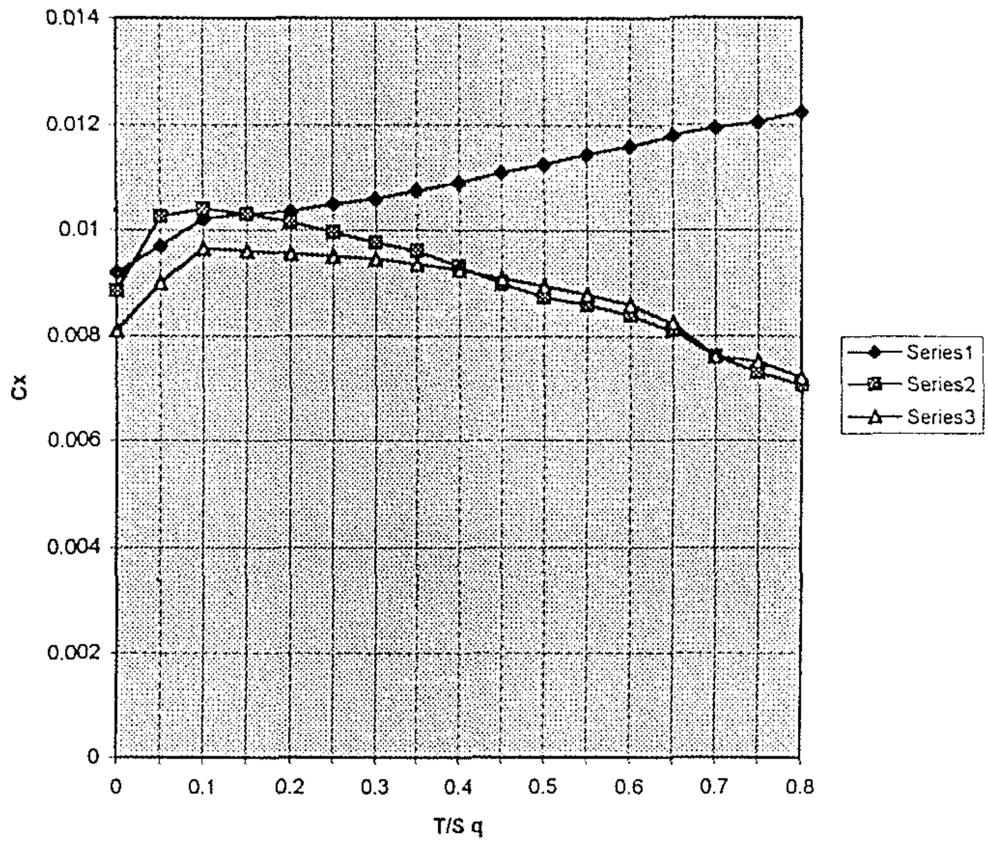

Fig. 4. Drag of fuselage without and with rotor work.

Model Ducted Tail Rotor Testing

We, in Poland, do not manufacture very large helicopters thus small ones mean low placed tail rotor. Such auxiliary rotors should be shielded to provide safety to people working or moving around. On the other hand, such a housing can positively influence the propeller propulsive efficiency and decrease the noise. That is why the problem has become vital enough for us to solve it.

We have built a stand to test the character of the propeller characteristics; the propeller was placed in the hole of a plate imitating a fin of a very large (in comparison to the propeller diameter) dimensions. We tested (using the hot wire anemometer technique) velocity field on both sides of the plate and pressure distribution on its both sides as well. The testing results enabled us to esteem how big such a fin can be to be worth of using and percentage watt-hour efficiency gain. The results received let discussing the flow model creating in such a system. Sample results from the stand are presented in pic. 5. We have not changed the plate thickness and the testing has been done for the hovering flight conditions.

Further testing will be carried out on the similar but larger stand (pic.6 – the propeller

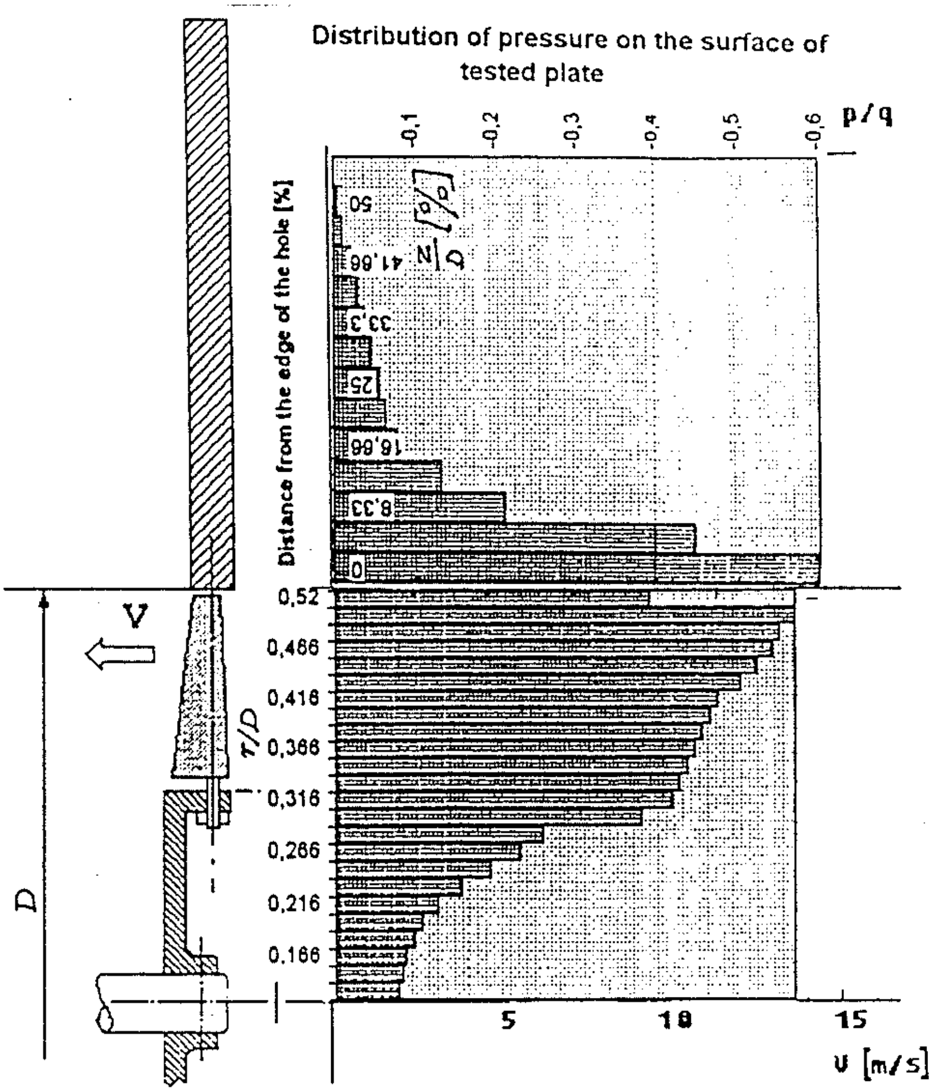

Fig. 5 Measurements of aerodynamic characteristics of ducted tail propeller

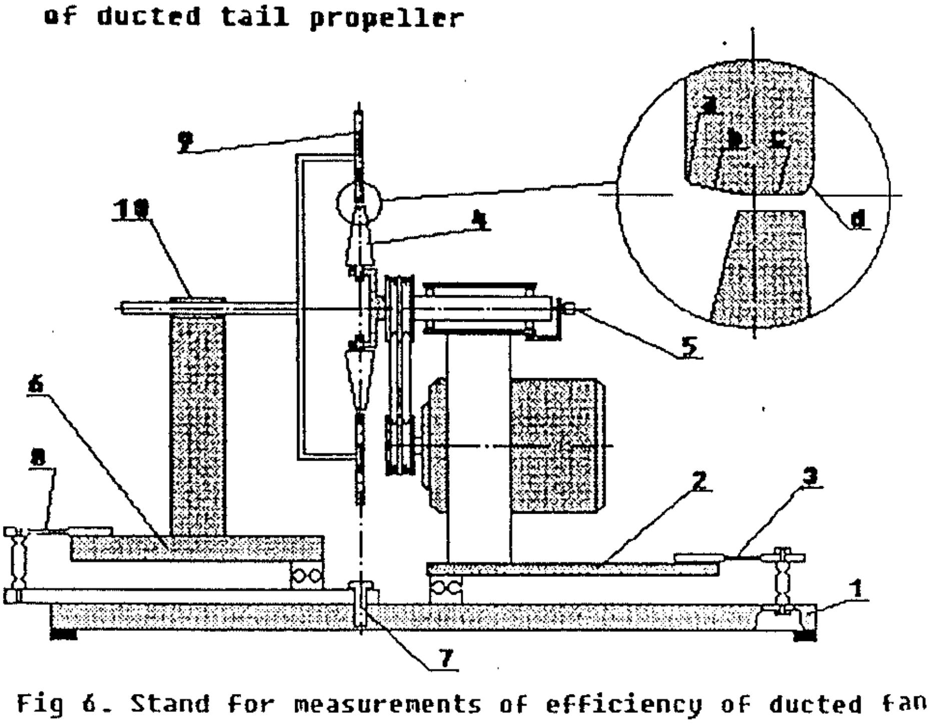

Fig 6. Stand for measurements of efficiency of ducted fan.

diameter up to 0.5 m.). Here the changeable quantities will be as follows: the number of the propeller blades (from 2 to 8), blade geometry and blade angle setting, the plate thickness, the channel where the propeller works geometry, the thickness and shape of a gap between the blade and the tunnel, parallel propeller plane shift against the fin plate, the angle between the planes. We plan to measure the following: electric motor power output, propeller rotation, its thrust, total amount of aerodynamic force acting on the plate imitating the fin, propeller generated noise level and blades vibrations when leaving the housing. The stand could be moved into the wind tunnel, so it will be possible to change the angle and flight speed vector value and induced velocity. It seems that the given and measured parameters number gives vast range of material necessary to design the ducted tail rotor. The testing is starting in September or October this year.

The Real Tail Propeller Testing

The testing done on the above described stand is a basic testing which can be employed while designing ducted tail rotors. However, the real tail propeller testing designed for a definite helicopter can be done on the rotor model testing stand adjusted to real tail rotors testing . Here, the IS-2 propeller shall have its original airscrew hub and controls system (with the force extensometer for the pusher); the power and rotation will be as in the real helicopter; the stand itself will be placed in the wind tunnel (of the 5m. in diameter testing space) to test the performance in skew flow conditions. The forces and their moments on the propeller, fin and controls system will be tested and measured here. Employing of the multi-channel contactless collector transmitting signals from high-speed rotating (up to 4,000 rpm) meter systems (e.g.: on-blades extensometers) to the computers collecting and handling the results makes it also possible to use the stand to test both, the tail rotor aerodynamically as a whole and the strength and durability of its elements. The chosen real helicopter parameters meter systems and warning devices will be diagnosed here as well.

The Simplified Full-scale Helicopter Model Dynamic Testing

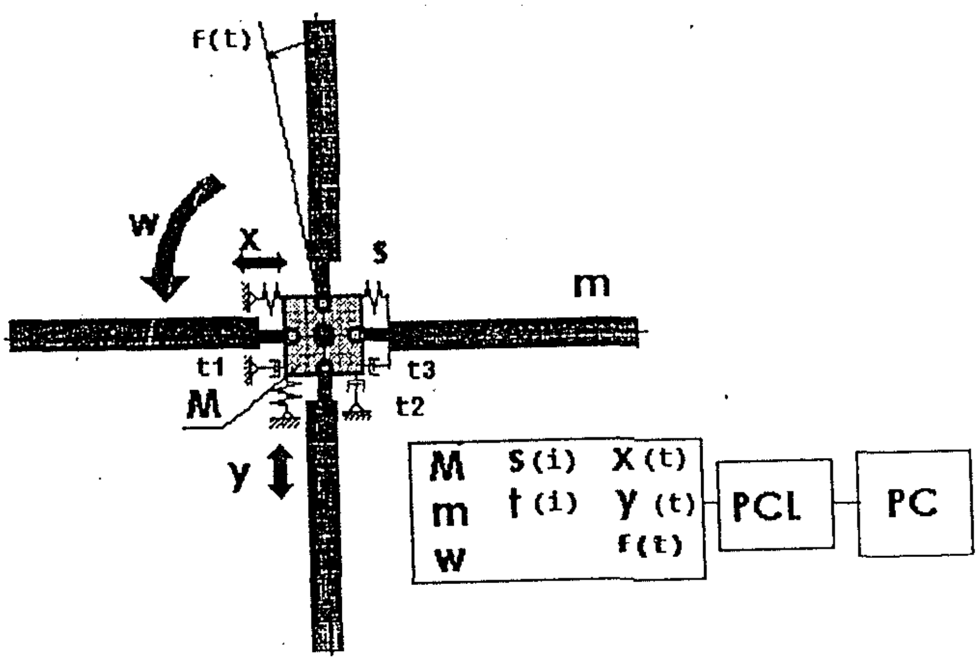

Fig. 7. Stand for verification of helicopter dynamic modeling

While the dynamic calculations at helicopter designing many programmes, various simplified assumptions and various boundary conditions are usually employed. To verify the mathematical model (especially for the ground resonance calculations accepted model) we have built a stand on which it is possible to work with two degrees of freedom of the fuselage mass; we model here the following parameters: mass distribution on helicopter, vibration damping and elasticity of the landing gear, rotor blades are suspended as in the used model (with elasticity and vibration damping), flapping, lagging and fuselage oscillations are measured. The rotor rotation is computer controlled. Any vibrations that appear, especially the resonance occurring (approaching) are recorded and analysed and their growth can be compared with the numeric calculations results.

The stand (pic.7) was used in the period in which we employed mostly our own calculation programmes; now it serves some educational purposes or is used to verify simplified assumption.

The Real Helicopter Units Testing

As it has been stated in the Introduction, there are among others, the Strength Department and Engine Department at the Institute of Aviation in Warsaw. Here we carry out proof and technological testing of helicopter units. At the Engine Department engine test beds we perform the testing of power transmission elements from the engine to the final drive. When the helicopter was a technical design, we tested belt transmission, belts strength, couplings and tighteners performance and their vibrations. Now, as the prototypes have been being built, the same testing is performed as the proof tests monitored by the control bodies.

At the same time, the elements and units of the helicopter supporting structure technological and proof tests are carried out at the Strength Department. We carry on the static strength and resonance strength testing; they help us to esteem the construction units and elements performance with vibrations acting at the foreseen frequency range. They are routine employed by our Institute when any aircraft is designed or tested. We use hydraulic inductors of adequate power, amplitude and frequency transmitted; the whole system is computer controlled. Of the all above mentioned tests, one is especially important: the power transmission to the tail rotor. Although a considerable number of helicopters has recently been produced (mainly Soviet licensed) in Poland, all the tail rotor propelling shafts were undercritical; they were built of short pieces connected by coupling; they were of a large diameter, thus being large and heavy. They needed a final, increasing rotation drive and so heavy again.

While the IS-2 helicopter designing, we decided to employ supercritical shaft transmitting power to the tail rotor. As it has been stated before, such a shaft has never been designed and manufactured in Poland so it was necessary to build a stand which would help to define parameters of the shaft going through critical rotation, both on rigid supports and on the elastic tail boom. Such a stand was designed and made. Apart from the security system (emergency case) and all the necessary characteristics testing (rotation, moment transmitted, vibrations amplitude in several sections) we provided it with controlled damping system for some chosen sections. The tests results will be used in the IS-2 helicopter designing.

The Real Helicopter Testing

The designing and making of the new helicopter require model first and real one testing finally. The process includes both, ready units and the whole helicopter testing. There is always the possibility of a failure or accident which can be dangerous for the testing team. That is why, knowing the long time testing of new units and ready helicopters, we have built a stand (pic. 8) consisting of foundation with helicopter fastening elements, a safety net (in case of rotor failure) and a testing and helicopter control room. A cable channel has been provided between a helicopter fastening place and the control room for testing wiring and controls elements. The dimensions of the whole stand were chosen so that it can serve medium helicopters testing. The safety net diameter (18m) and its height (11m) should meet the demand. It seemed that the testing stand without a pilot inside the tested object is absolutely acceptable solution; the possibility to enlarge the testing programme scope to extreme without any threat and danger for people is comfortable for the testing team.

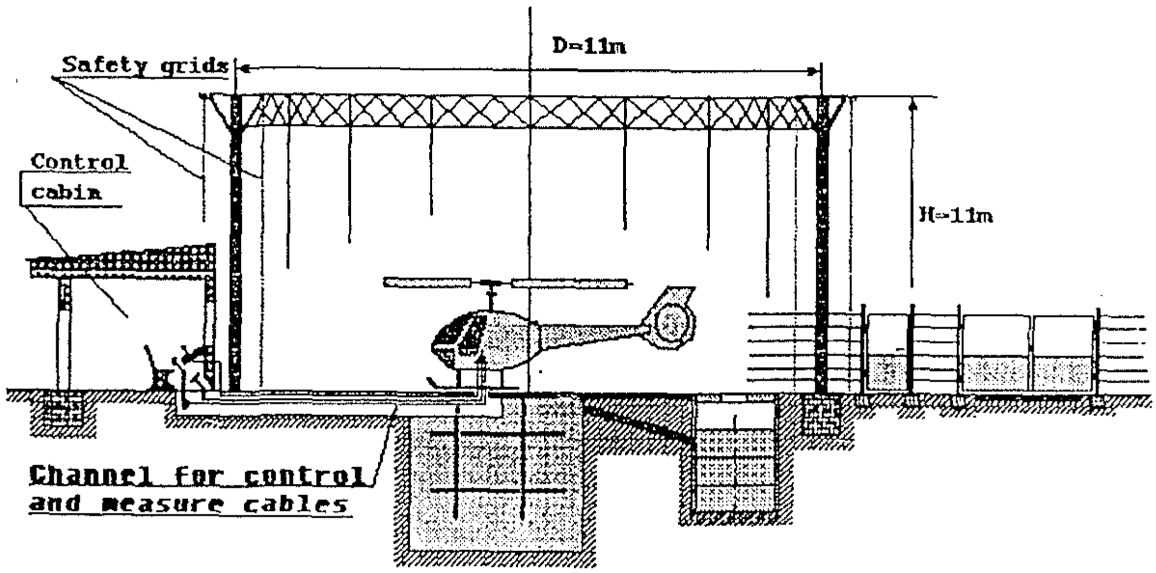

Fig. 8 Stand for safety tests of helicopters

First part of the testing inside the stand pertains to the IS-2 helicopter final drive durability. It would be replacing rotor loaded and mounted on a special tower (to lower ground influence), Diesel engine propelled (to decrease the cost) and the power transmission from the engine to the drive will go similar to the real one way.

Summary

The presented above, employed by the Institute of Aviation methods of the helicopter problems testing, described the existing testing stands and presented chosen tests results prove the real possibilities of performing both research and development and service work for industry. The majority of the methods presented comply with the international aviation regulations and their performance is monitored by the control bodies. Several testing results obtained with the help of the methods described have been published in the booklets 'Prace Instytutu Lotnictwa' (" The Institute of Aviation Papers").