HELICOPTER DURATION RESEARCH

NARAM-29 R & D Project

by Tim Barklage

OBJECTIVES

The objective of this research was to determine the optimum blade angle and rotor RPM for the maximum duration in a helicopter recovery system. In talking to numerous rocket modelers it appeared that there are two schools of thought for helicopter duration events. One is that you should seek as high a rotor RPM as possible, and the other just the opposite: that a low RPM would result in maximum duration. There was very little direct evidence supporting either side and no research to determine the answer. My goal in this research was to determine the best blade angle for maximum duration.

THE APPROACH TAKEN

This research was conducted in three phases. Phase one was a study of rotorcraft aerodynamics. This study was to determine what was actually happening to the airflow of the rotor system during autorotation and to develop a working theory for further experimentation and testing.

The second phase was the test phase. This was a series of experiments under as close to laboratory conditions as possible to test various rotor configurations.

The last phase was the data reduction phase that would correlate the test results into a usable format and point the way for any further research.

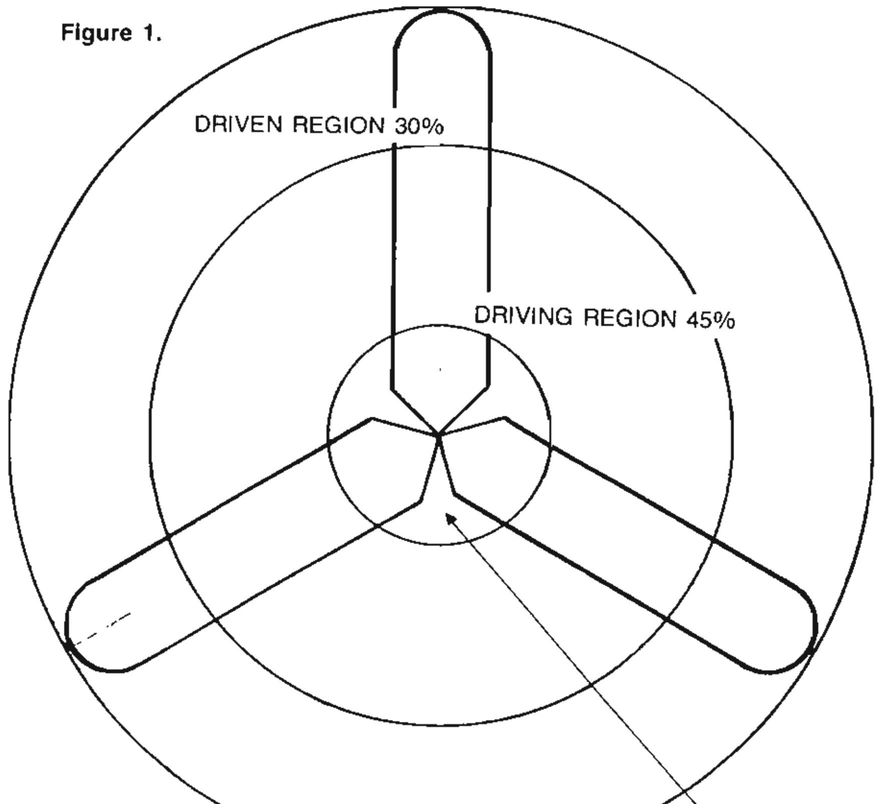
EQUIPMENT USED

The equipment used was a test vehicle developed from a "Reverse Helix" designed by John Pursley. This helicopter duration model was modified by attaching the blades with a metal rod and setscrew, allowing the blade angles to be changed and locked into place. The model was then drop-tested from the Baton Rouge Metro Airport control tower. This tower is 150 feet tall and has a catwalk around the cab that made a perfect platform for drop-testing. Drop testing was chosen to reduce the added variables involved in launching the model by rocket motor. Two standard stopwatches were used to time each drop and an Atari 800 computer was used to correlate the data into a graph.

DATA COLLECTED

The research into rotorcraft aerodynamics led me to a U.S. Army publication FM 1-203 on helicopter aerodynamics. The Army has studied this area for many years with their interest being in the area of autorotations after a power loss. While most helicopter autorotations are done with forward airspeed, and a helicopter recovery system is a vertical descent, the Army has studied both. An examination of FM 1-203 shows that during a vertical autorotation the rotor disk can be divided into three regions, as shown in figure 1.

Figure 1.



a. The driven region or propeller region. This region is nearest to the rotor tips and extends approximately 30% of the blade length. Because of the higher speed at the tip this part of the blade provides the lift that slows the rate of descent. This lift also causes drag that tends to slow the rotation of the blade.

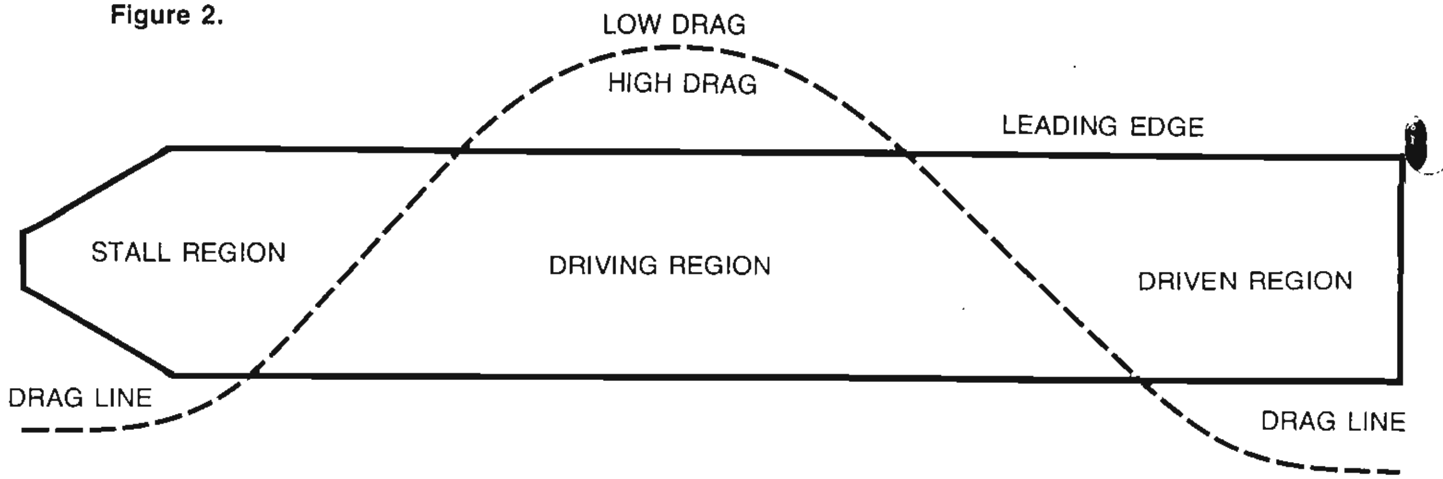
b. The driving region or autorotative region. This area normally lies between 25 to 70% of the blade length. Because of the lower speed of this portion of the blade and its angle of attack it provides the forces needed to turn the blades in autorotation.

c. The inboard 25% of the blade is known as the stalled region. Due to the slow speed of the blade at this point it is stalled, producing no lift, only drag.

Figure 2 shows the relationship of these three areas on a rotor blade. The dashed line is the drag ratio line. Any given rotor blade, if allowed to autorotate, will achieve a steady and constant RPM where the drag and thrust regions become equal. This point of equilibrium will produce a specific amount of lift. A higher angle of attack will produce more lift, but will also produce more drag as the stalled region increases. This slows the RPM, producing less lift. A lower angle of attack will cause less drag and an increase in RPM. This increase in RPM will cause more lift due to the higher speed at the tips but the higher RPM will also result in a higher rate of descent. An angle of attack must be found that will balance these opposing forces at an RPM that provides the smallest rate of descent. This is discussed and illustrated in U.S. Army manual FM 1-203, Section IV (Autorotation), pp. 3-45, 3-46, 3-47.

A program was designed that would experimentally find the blade angle of attack to give an RPM that will provide the greatest amount of lift and least rate of descent, thus the longest duration. The test vehicle was set with an initial blade setting of 0 degrees. Four drops were made and

Figure 2.



the times averaged. The blade angle was then changed four degrees and another four drops were made. This process was continued until the angle of attack reached a point that inhibited rotation. The data from these drops indicate the lowest rate of descent was at an angle of attack of 8 degrees. To narrow the range, a second series of drops was then conducted using settings two degrees above and below this angle. Four drops each were made at 6 degrees and 10 degrees in this second series. The combined data obtained in both series are shown in table 1. A graph was produced with these data and it is shown in figure 3.

THE RESULTS OBTAINED

An examination of both graphs show that as I increased the angle of attack the rate of time required to drop the same distance increased. Observation of the drops revealed that rotor RPM was decreasing with each increase of angle of attack. However when the angle of attack reached 10 degrees the RPM continued to decrease but the time to drop also decreased, indicating a faster rate of descent. From this I have determined that the best angle of attack for a "Reverse Helix" with flat blades is 8 degrees. Since the only other variable is the shape of the blade, we can also deduce that this setting would hold true for any flat blade.

CONCLUSIONS

If a modeler designs a helicopter recovery system with flat blades, then he should design it with an angle of attack of 8 degrees. This angle of attack should be measured from a reference line that is 90 degrees from the long axis of the rocket as shown in figure 4. If a modeler designs a helicopter recovery system that has any airfoil to the blades, then the only way to find the optimum angle of attack is by drop-testing. A tower or building at least 100 feet tall will be required. It should be clear of any building on the downwind side and not have any wires or other obstruction to a free drop. A test vehicle should be designed that will allow the angle of attack to be changed between drops. This model can be designed with a simple rotor hub that the blades are attached to with masking tape. Once the best angle has been determined by drop-testing the test vehicle, the blades are attached to the actual model with this angle built in.

PLANS FOR FUTURE RESEARCH

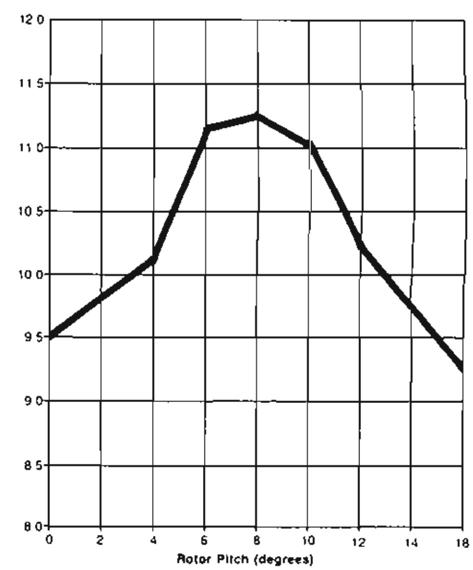
My research indicates that the drag on the driven part of the blade is a direct result of the lift obtained and therefore cannot be reduced without reducing the lift. However the drag associated with the stalled region of the blade provides no lift. My next project will be to design a blade that will reduce this drag to a minimum. Two approaches present themselves. One, a low drag spar on the blade that will extend the blade away from the rocket body tube. The second is to twist the blade to decrease the angle of attack at the hub, then increase it towards the tip. This should reduce the stalled region, move the driving region in and increase the propeller region providing more lift at the same RPM. Because of the need for high strength and low weight at the hub the second approach seems to offer the most promise. Since we now have two factors to consider, angle of attack and degree of twist, drop-testing will be more complex.

Drop-testing can be a valuable tool in the design and development of all types of rocket recovery systems. It allows the experimenter to play with different configurations without the expense of multiple rocket launches or the chance of damage during boost.

TABLE 1
DROP TIMES
(seconds)

Rotor Angle (deg.)	D1	D2	D3	D4	AVG.
0	9.50	8.95	10.14	9.53	9.53
4	8.21	9.91	10.48	11.95	10.14
6	11.09	11.30	10.80	11.20	11.10
8	13.92	10.05	10.33	10.51	11.20
10	11.00	11.04	10.95	11.09	11.02
12	10.34	8.41	10.57	11.77	10.27
16	9.41	10.25	9.17	8.25	9.27

Figure 3
Drop Times vs. Rotor Angle



RockeTip: When masking off large ares of a model for spray painting, do not use porous materials such as typing paper or grocery bag paper. Paint can soak through these and ruin your model! Use finished, glossy paper such as magazine covers or even plastic bags.