



NORMAL THRUSTING STATE

- FOR HOVERING AT LOW RATES OF DESCENT, THE INDUCED FLOW GENERATED BY THE BLADES EXCEEDS THE RATE OF DESCENT. THE AIRFLOW IS DOWN WITH RESPECT TO THE ROTOR DISK.
- THERE IS A DIFFERENCE IN INDUCED FLOW VELOCITIES ALONG THE BLADE SPAN. THIS RESULTS FROM THE VARYING ROTATIONAL VELOCITIES AND ANGLES OF ATTACK FROM THE ROOT TO THE TIP OF THE BLADE.
- THE THRUST GENERATED BY THE ROTOR SYSTEM IS QUITE STEADY, AND ENGINE POWER REQUIRED TO MAINTAIN ROTOR RPM REMAINS CONSTANT.



CHICKEN PLANT

VORTEX RING STATE

- AT GREATER RATES OF DESCENT, THE WIND DEVELOPED BY THE VERTICAL VELOCITY OF THE HELICOPTER IS OPPOSING THE NORMAL INDUCED FLOW DEVELOPED BY THE ROTOR.



- THIS UPWARD FLOW OF AIR CANCELS THE INDUCED FLOW AND, IN FACT, ALLOWS AN UPWARD FLOW OF AIR IN THAT PART OF THE ROTOR DISK WHERE THE UPWARD VELOCITY OF FLOW EXCEEDS THE INDUCED FLOW VELOCITY.
- THIS RESULTS IN AN UNSTEADY TURBULENT FLOW OF AIR THROUGH THE ROTOR DISK AND INCREASING RATES OF DESCENT, EVEN THOUGH ADDITIONAL POWER IS SUPPLIED BY THE ENGINE.





AUTOROTATIVE STATE

- AT RATES OF DESCENT EXCEEDING THE VORTEX RING STATE, THE AUTOROTATIVE STATE IS ACHIEVED. AT THESE HIGHER RATES OF DESCENT, THE TURBULENT, UNSTEADY FLOW BEGINS TO SMOOTH OUT.
- THERE IS SOME RATE OF DESCENT WHERE NO ENGINE POWER IS REQUIRED TO MAINTAIN ROTOR RPM. THE ROTOR SYSTEM IS EXTRACTING ENOUGH ENERGY TO PROVIDE THE POWER REQUIREMENT FROM THE AIR IN THIS STATE OF VERTICAL FLIGHT.



- THE AUTOROTATIVE STATE IS THE BOUNDARY BETWEEN CONDITIONS WHERE ENGINE POWER MUST BE DELIVERED TO THE ROTOR TO PREVENT ROTOR RPM DECAY AND WHERE POWER MUST BE EXTRACTED FROM THE ROTOR SYSTEM TO PREVENT ROTOR OVERSPEED.





WINDMILL BREAK STATE

- AT VERY HIGH RATES OF DESCENT, THE AIRFLOW IS ALMOST ENTIRELY UP THROUGH THE ROTOR SYSTEM. THE ROTOR SYSTEM IS ACTING SIMILAR TO A WINDMILL. IT IS EXTRACTING MORE ENERGY FROM THE AIR THAN IS REQUIRED FOR FLIGHT.
- IT IS NOT A NORMAL OPERATING STATE FOR THE ROTOR SYSTEM; SOME ENERGY MUST BE EXTRACTED TO PREVENT A ROTOR OVERSPEED. THIS CAN USUALLY BE ACCOMPLISHED BY INCREASING COLLECTIVE PITCH, WHICH ADDS MORE DRAG TO THE SYSTEM.

