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THE MULTIPURPOSE COMPOSITE FLYWHEEL

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TWIN DISK COMPOSITE FLYWHEEL

The Twin Disk Composite Flywheel (Figure 1) represents a breakthrough in the state of the art of flywheels. It shows that the techniques that were developed at Rocketdyne to successfully design, fabricate and test high-speed rotating machinery (turbopumps) for rocket engines could be used to develop advanced flywheels. This flywheel not only demonstrates that successful mating of metal flywheel characteristics (high torque and ruggedness) and composite flywheel characteristics (lightweight and high energy density) can be achieved, but the unique design lends itself to easy adaptation to other configurations.

Figure 1

DESIGN CRITERIA

This flywheel was designed and fabricated under a DOE-Sandia contract (1978). It was the purpose of this contract to develop a composite flywheel for automotive use. The wheel was required to store between 1.0-5.0 kW-hr of useable energy to be dissipated through a 3:1 duty cycle. The envelope requirements were 0.6-m maximum diameter by 0.2-m maximum thickness. Two full-size, system ready units were made.

DESIGN CRITERIA

- USE NOMINAL MATERIAL PROPERTIES MINUS 3σ
- USE 2.0 FACTOR OF SAFETY (ULTIMATE)
- USE 1.5 FACTOR OF SAFETY (FATIGUE - 3:1 DUTY CYCLE)
- FLYWHEEL WEIGHT - 53 kg
- RATED SPEED - 22,000 RPM
  - 1.6 kW-hr ENERGY STORED
  - 30 W-hr/kg ENERGY DENSITY

DESIGN FEATURES

- TWIN ALUMINUM DISKS
  - GIVES HIGH TORQUE CAPABILITY
- ALUMINUM MANDPᴱL RING
  - AIDS FABRICATION
  - TRANSMITS TORQUE
- GRAPHITE/EPOXY RIM
  - HIGH ENERGY STORAGE
  - HIGH ENERGY DENSITY
- RADIAL PINS
  - CARRIES TORQUE
  - PERMITS RADIAL GROWTH

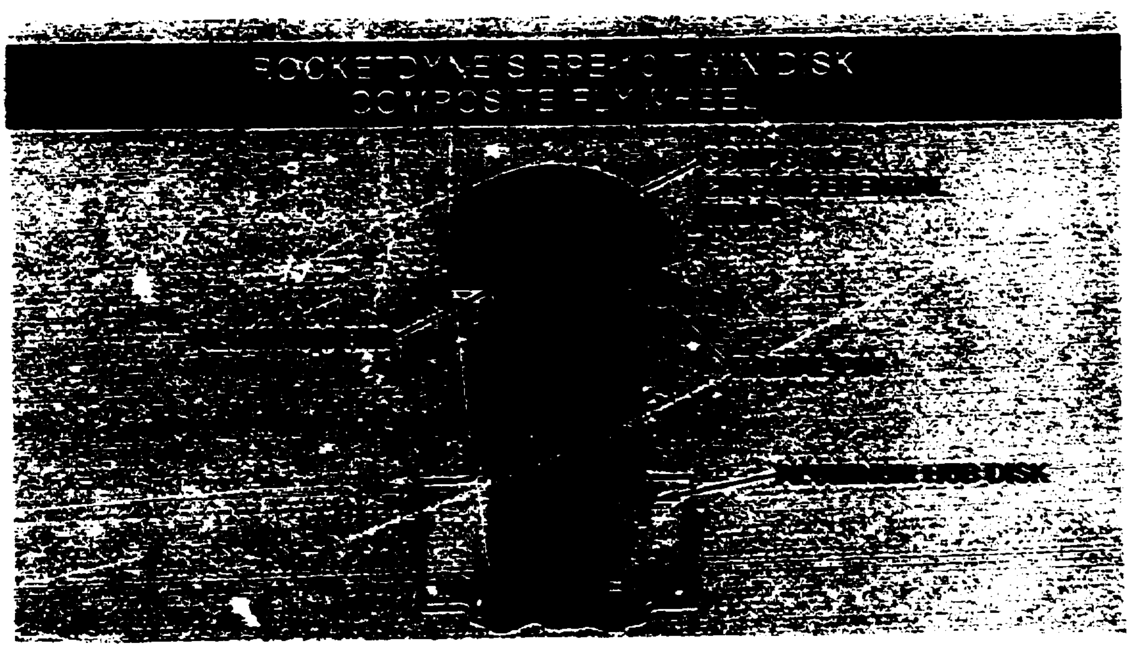

Figure 2

FABRICATION, ASSEMBLY AND BALANCE

The aluminum parts were fabricated and assembled into a subassembly which was dynamically balanced. After the graphite/epoxy composite matrix was wound onto the wheel, the entire "composite flywheel" was dynamically balanced in bearings (Figure 3).

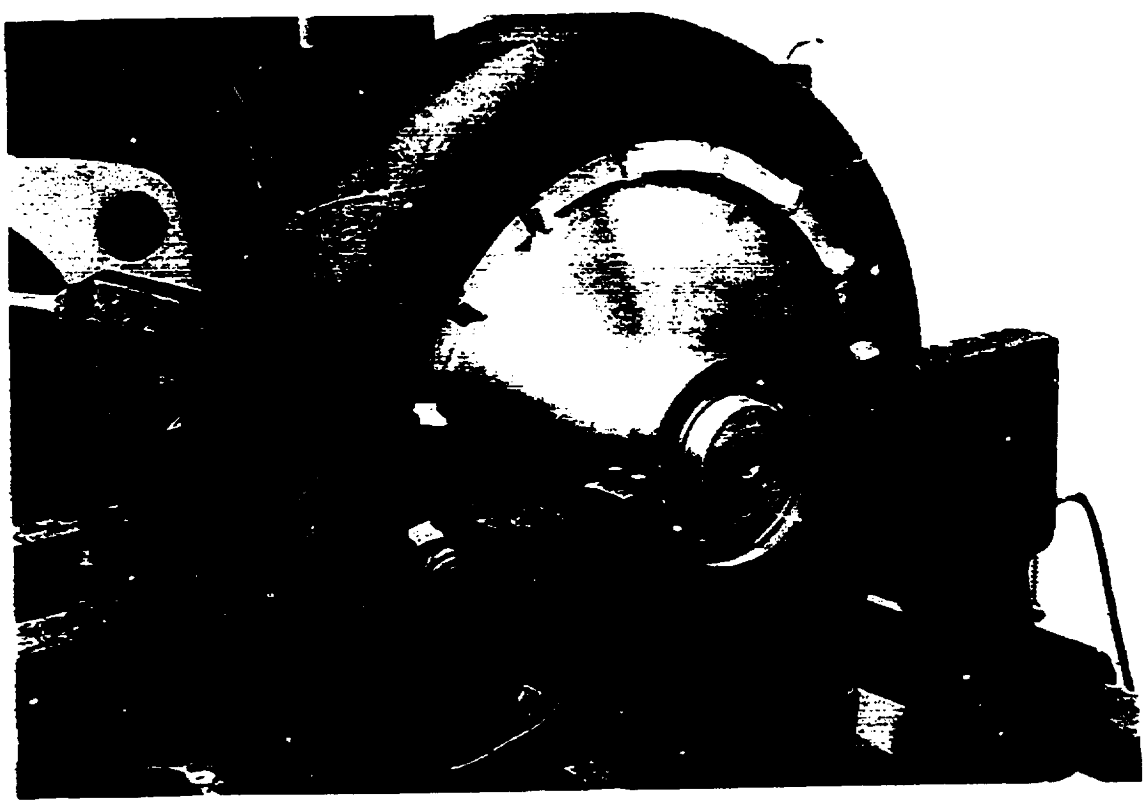

Figure 3

TESTING AT DOE

The flywheel was tested by DOE at the Oak Ridge National Laboratory Spin Test Facility in August of 1980 and March of 1981. The results are summarized bolow

Test No.	Date	Top Speed RPM	Remarks
1	8/12/80	12,000	High-Speed Balance Checkout
2	8/14/80	17,040	Dynamically Stable
3	8/15/80	20,718	Dynamically Stable
4	8/18/80	6,000	Facility Checkout
5	8/19/80	22,000	Rated Operating Speed
6	8/20/80	22,920	30 minutes of successful operation over 22,000 RPM
7	3/05/81	6,000	Facility Checkout
8	3/06/81	15,000	High-Speed Balance Checkout
9	3/09/81	20,500	Test Terminated Pressure Rise
10	3/10/81	24,120	Test Terminated Facility Limitation
11	3/10/81	6,000	Data Verification

TEST RESULTS

- DESIGN CONCEPT PROVEN
  - 11 TESTS AT DOE WITHOUT FAILURE
  - MAXIMUM SPEED OVER 24,000 RPM
  - OVER 2 kW-hr TOTAL STORED ENERGY
  - OVER 40 W-hr/kg ENERGY STORED (OPERATIONAL)
- HIGHER ENERGY VALUES NOW POSSIBLE
  - NEW MATERIALS (1978 VS 1985)
  - WIDER WHEEL - 2:1 ASPECT RATIO
  - 2:1 DUTY CYCLE

APPLICATIONS

The metallic twin disks allow this flywheel to be used in applications where a high torque capability is necessary. Attachment can be accomplished directly through couplings or splines, or a variety of clutches can be used (Figure 4).

HIGH TORQUE CAPABILITY

- ALLOWS DIRECT COUPLING WITH MOTOR/GENERATORS
- ALLOWS COUPLING TO SEPARATE MOTORS AND GENERATORS
- ALLOWS FOR DIFFERENT CHARGE/DISCHARGE RATES
- ALLOWS FOR HIGH POWER DENSITY DRAIN RATES

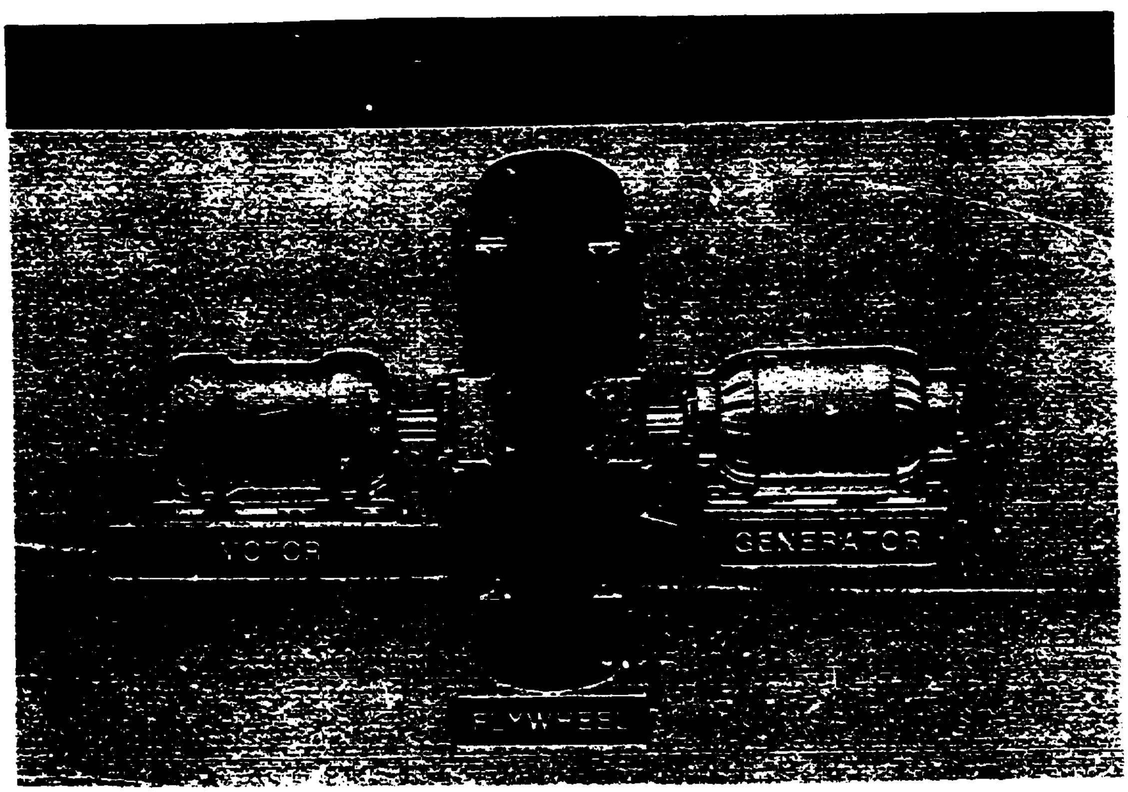

Figure 4

SCALABLE AND STACKABLE

This design is both scalable and stackable. Design studies of similar wheels with energy storage capacities of 1 kW-hr to 1 MW-hr have been accomplished without difficulty. Identical disk profiles have been successfully stacked as part of Rocketdyne's RPE-13 Flywheel Power Module being used to power a coal mining shuttle car (Figure 5).

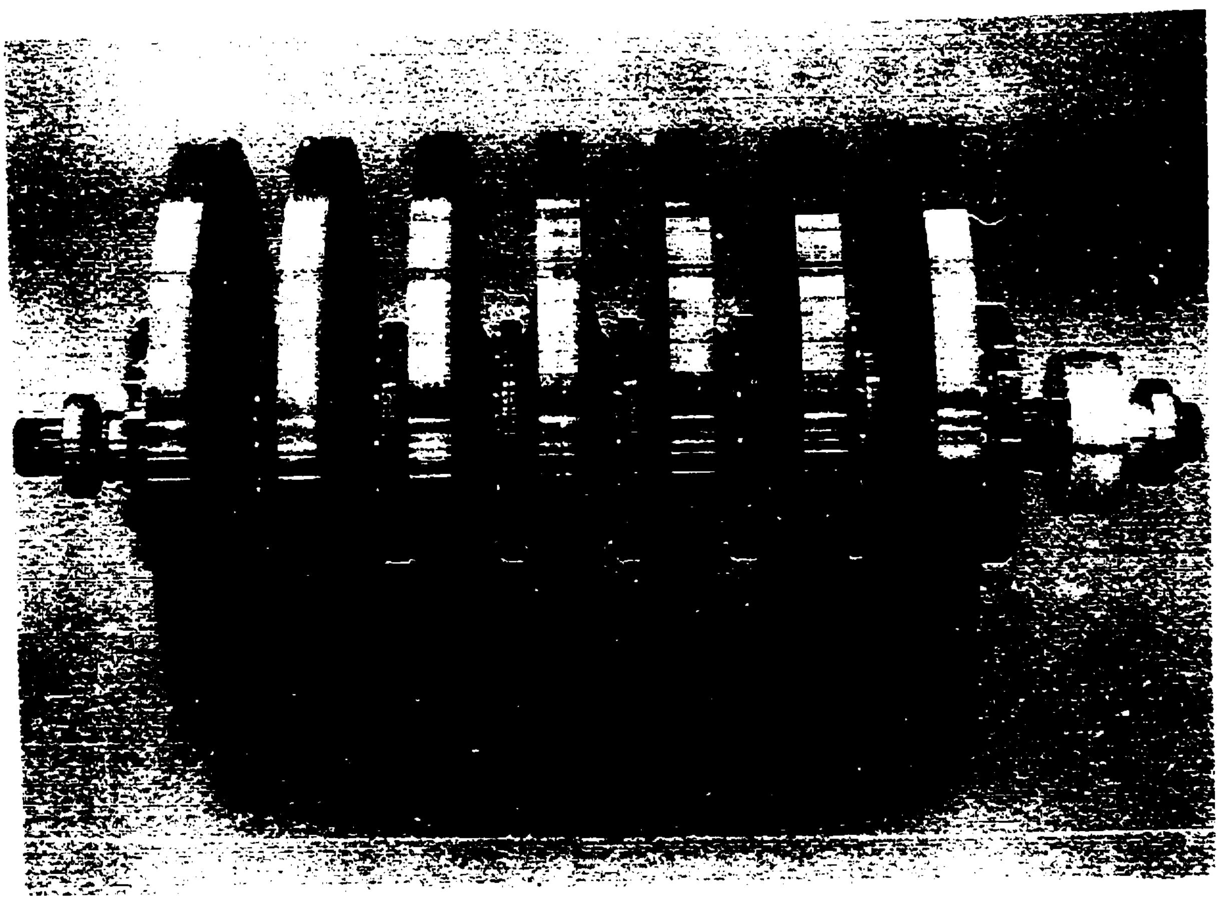

Figure 5

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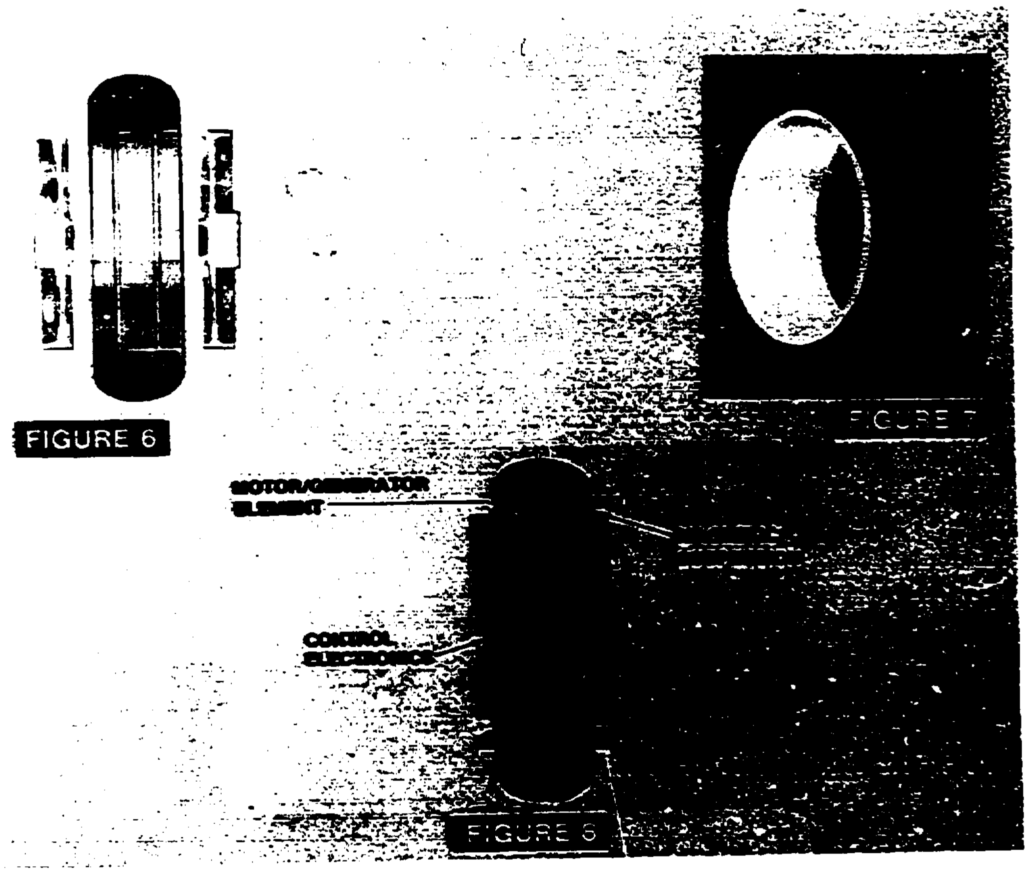
ADAPTABLE

The unique design of this flywheel allows the side disks to be removed (Figure 6) leaving just the composite rim with the aluminum inner ring (Figure 7). This can then be readily adapted to other uses such as advanced AMCD or a brushless D/C motor/generator (Figure 8).



CONCLUSION

A composite flywheel has been designed, fabricated and tested by the same techniques used to successfully develop high-speed rotating machinery on various NASA programs. This flywheel is available for use in space-station proof-of-concept testing without further development.

- STATE-OF-THE-ART BREAKTHROUGH
- OVER 2 kW-hr STORED IN DOE TEST WITHOUT FAILURE
- HIGHER VALUES POSSIBLE NOW
- RUGGED CONSTRUCTION
- HIGH TORQUE CAPABILITY
- SYSTEM READY - DUAL BEARINGS
- SCALABLE
- STACKABLE
- ADAPTABLE
  - ADVANCED AMCD
  - ADVANCED BRUSHLESS MOTOR/GENERATOR
- AVAILABLE
  - FOR PROOF OF CONCEPT TESTING
  - WITHOUT FURTHER DEVELOPMENT