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(54) **COMBINED STAGE SINGLE SHAFT TURBOFAN ENGINE**

(75) Inventors: **Anthony Jones**, San Diego, CA (US);  
**Mark Harris**, San Diego, CA (US);  
**Patrick Lydon**, San Marcos, CA (US);  
**Eric Alexander**, San Diego, CA (US)

(73) Assignee: **Hamilton Sundstrand Corporation**,  
Rockford, IL (US)

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See application file for complete search history.

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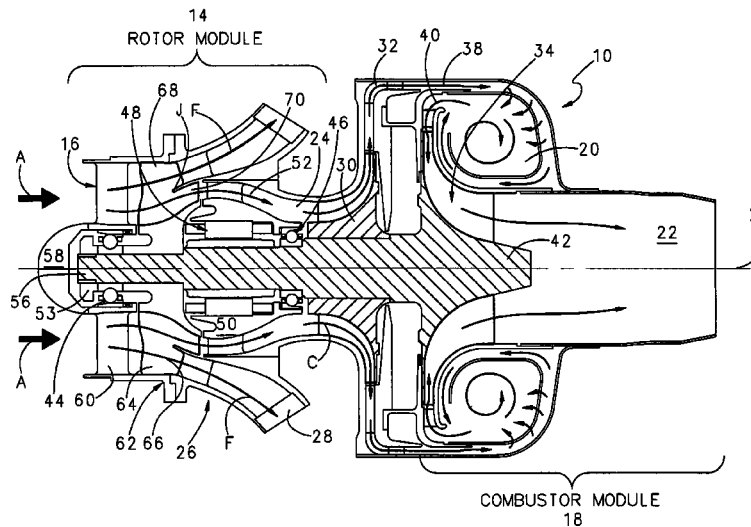
*Primary Examiner*—William H. Rodriguez

(74) *Attorney, Agent, or Firm*—Carlson, Gaskey & Olds

(57) **ABSTRACT**

A turbofan engine includes a combined stage rotor mounted for common rotation with a shaft, a compressor stage, and a turbine stage. Each of the plurality of fan blades of the combined stage rotor are contiguous with a respective compressor blade. The combined stage rotor is located at a junction between a fan bypass duct and a core duct. The fan bypass stage portion includes a plurality of the fan blades which communicate incoming airflow into fan bypass airflow through the fan bypass duct. The compressor stage portion includes a plurality of the compressor blades which communicated airflow into core airflow through the core duct. The plurality of fan blades extend substantially perpendicular to the plurality of compressor blades such that the plurality of compressor blade portions extend at least partially into the core duct and preferably will include splitters for enhanced efficiency.

**26 Claims, 2 Drawing Sheets**



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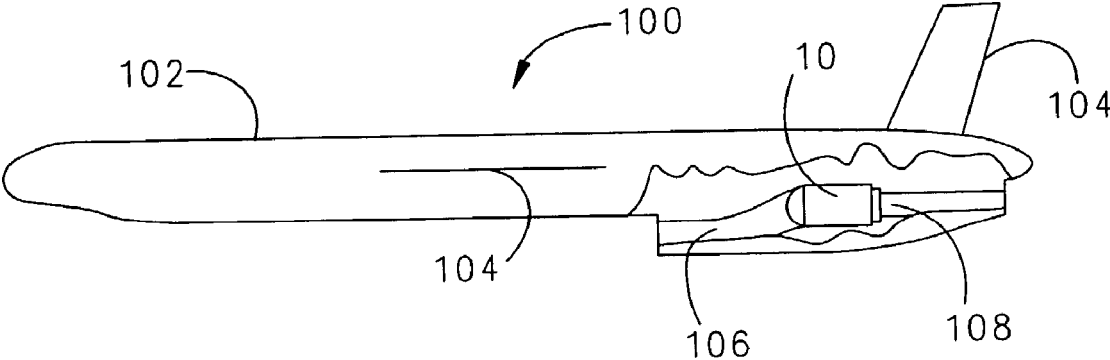


FIG. 1

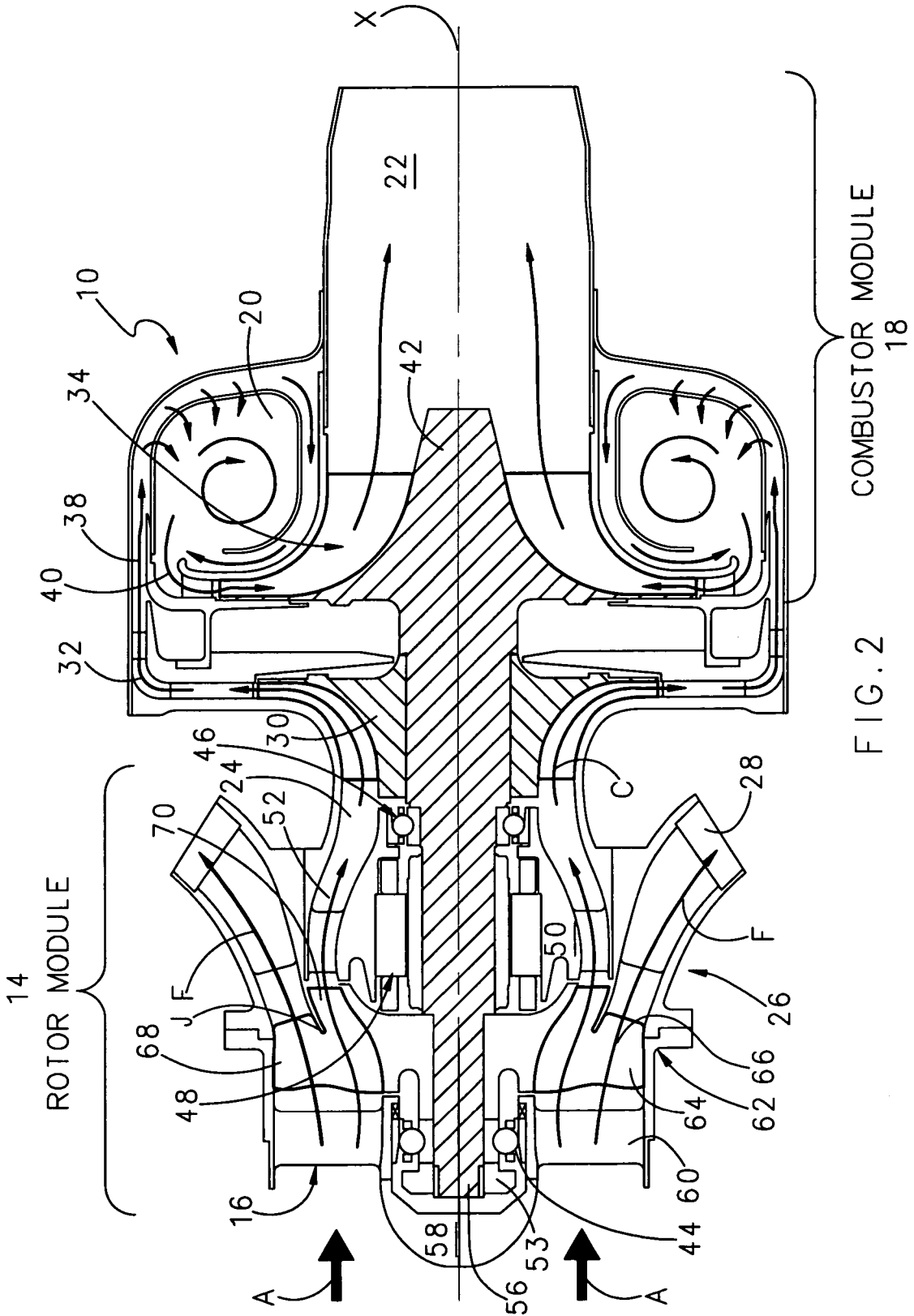


FIG. 2

## COMBINED STAGE SINGLE SHAFT TURBOFAN ENGINE

### BACKGROUND OF THE INVENTION

The present invention relates to a miniature turbofan engine, and more particularly to a combined stage rotor which combines a fan and compressor into single stage.

Miniature turbojet engines are often utilized in single usage applications such as reconnaissance drones, cruise missiles, decoy and other weapon applications. Although providing high thrust, conventional miniature turbojet engines typically consume relatively large quantities of fuel. High fuel consumption reduces the effective range of the aforementioned vehicles.

Turbofan engines are conventionally utilized in commercial and military applications as such engines provide high thrust and fuel efficiency. Turbofan engines are relatively complex and heretofore have not been often utilized in a miniaturized form for single usage applications due to their expense.

Accordingly, it is desirable to provide a turbofan engine which provides high thrust and fuel efficiency with a relatively inexpensive and uncomplicated design.

### SUMMARY OF THE INVENTION

The turbofan engine according to the present invention provides a combined stage rotor mounted for common rotation with a shaft compressor stage and turbine stage. The combined stage rotor is located at the junction between a fan bypass duct and a core duct. The fan bypass stage portion and the compressor stage portion is a single unitary wheel which rotates with the shaft, the compressor, and the turbine.

The fan bypass stage portion includes a plurality of fan blades which communicate incoming airflow into fan bypass airflow through a fan bypass duct. The compressor stage portion includes a plurality of compressor blade portions which communicated in common airflow into core airflow through a core duct. The plurality of fan blades define an outer diameter greater than the plurality of compressor blade portions. The plurality of fan blades also extend substantially perpendicular to the plurality of compressor blade portions such that the plurality of compressor blade portions extend at least partially into the core duct.

As the fan bypass stage portion and the compressor stage portion rotates with the single common shaft, the compressor stage portion boosts the pressure ration and power of the core thereby providing high thrust and fuel efficiency with a relatively inexpensive and uncomplicated design.

### BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the currently preferred embodiment. The drawings that accompany the detailed description can be briefly described as follows:

FIG. 1 is a general perspective view an exemplary vehicle embodiment for use with the present invention; and

FIG. 2 is a sectional view of a turbofan engine, specifically a turbofan embodying a combined stage rotor according to the invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates a general schematic view of a vehicle **100** including a turbofan engine **10** according to the present invention. The vehicle **100** includes a body **102** and one or more aerodynamic surfaces **104**. The engine **10** is coupled to, or within, the body **102**. An intake **106** provides air to the turbo fan **10**, and an exhaust pipe **108** is adapted to exhaust the thrust from the turbofan **10**. It should be understood that multiple intakes and exhaust will benefit from the present invention. The turbofan engine of the present invention may also be used in other single usage and reusable applications such as reconnaissance drones, cruise missiles, decoys and other weapon and non-weapon applications.

Referring to FIG. 2, the turbofan engine **10** includes a housing **12** defining a longitudinal axis X, a rotor module **14** having a forward inlet **16**, and a combustor module **18** including a combustion **20** and an exhaust pipe (nozzle) **22**. The turbofan **10** is defined by a core section **24** at least partially surrounded by a fan bypass section **26**.

As generally understood, airflow A entering the forward inlet **16** is split between fan bypass airflow (illustrated schematically by arrow F) and core airflow (illustrated schematically by arrow C). The fan bypass airflow F passes through the fan bypass section **26** where it is communicated overboard through a fan bypass duct **28**. The core airflow C passes through the core section **24** where it is heated and compressed prior to being exhausted through the exhaust pipe **22**.

A compressor **30** and a compressor diffuser **32** are provided between the inlet **16** and the combustor **20**. A turbine **34** is provided between the combustion **20** and the exhaust pipe **22**. The compressor **30** discharges in a radial direction to the diffuser **32**. The compressed air is then directed to a plenum **38** about the combustor **20** and enters the same to provide for the combustion of fuel within the combustor **20**.

The combustor **20** includes an outlet **40** to the turbine **34** so as to rotate the turbine stage **34**. A shaft **42** is rotatably mounted on a forward bearing **44** and an aft bearing **46** to couple the compressor **30** and the turbine **34** stage together such that rotation of the turbine **34** cause rotation of the compressor **30**. Most of the energy of the gases of combustion, however, is directed out of the exhaust **22** to provide thrust.

An electric starter generator **48** is coupled to the shaft **42** to spin the shaft **42** on starting the engine and to generate power during engine **10** operation. A fairing **50** mounted about the electric starter generator **48** preferably defines the core airflow C path through a core duct **52** in the core section **24** prior to communication with the compressor **30**.

A forward extension **56** of the shaft **42** is preferably mounted in a forward fairing **58** located within the intake **16** by struts **60**. The shaft **42** may be coupled to a fuel pump (illustrated somewhat schematically at **53**) which provides fuel to the combustor **20** through fuel injectors (not shown) or the like.

A combined stage rotor **62** is preferably mounted for common rotation with shaft **42** upstream of the compressor **30**. The combined stage rotor **62** is preferably located at a junction J between the fan bypass duct **28** and the core duct **52** such that the combined stage rotor **62** essentially spans the fan bypass section **26** and the core section **24**.

The combined stage rotor **62** is a combined fan bypass stage portion **64** contiguous with a compressor stage portion **66**. That is, the fan bypass stage portion **64** and the com-

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pressor stage portion **66** are a single unitary wheel which rotates with shaft **42**, compressor **30**, and turbine **34**.

The fan bypass stage portion **64** includes a plurality of fan blades **68** which communicate incoming airflow **A** into fan bypass airflow **F** through the fan bypass duct **28**. The compressor stage portion **66** includes a plurality of compressor blades **70** which communicate airflow **A** into core airflow **C** through the core duct **52**. That is, each fan blade **68** is contiguous with a corresponding compressor blade **70** which respectively divides airflow **A** into fan bypass airflow **F** and core airflow **C**.

The plurality of fan blades **68** preferably define an outer diameter greater than the plurality of compressor blades **70**. The plurality of fan blades **68** also preferably extend substantially perpendicular to the plurality of compressor blades **70** such that the plurality of compressor blade portions **70** extend at least partially into the core duct **52**. That is, each fan blade **68** and each compressor blade **70** forms an essentially L-shaped rotor blade. It should be understood that various rotor shapes will benefit from the present invention depending upon the shape of the fan bypass duct **28** and the core duct **52** and their relative relationship.

In operation, the shaft **42** is spun up through the starter generator or other arrangement such as a solid fuel motor to rotate the combined stage rotor **62**, the compressor **30** and the turbine **34** as air begins to enter the combustor **20**. A vaporized liquid fuel, e.g., diesel fuel or Jet A kerosene, is injected into the combustor **20**, such that the temperature is high enough to allow the liquid fuel to sustain itself in a stable, constant, burn. The burn of the liquid fuel heats the combustor **20** and the compressed air within, and the heated, high pressure air is expelled through the exhaust pipe **22**. The turbine **34** absorbs the necessary energy from the expelled gases to power the compressor **30** and the combined stage rotor **62**, with the greater part of the energy utilized to develop propulsive thrust.

As the fan bypass stage portion **64** and the compressor stage portion **66** rotates with shaft **42**, the turbofan engine **10** provides high thrust and fuel efficiency with a relatively inexpensive and uncomplicated design which does not require independent counter rotating shafts or a separate fan stage.

The combined stage rotor according to the present invention can be manufactured sufficiently economically as to have, if desired, a single-usage capability. Moreover, the high fuel efficiency achieved by the turbofan construction achieved by the combined stage rotor is well suited for use in environments requiring a small envelope while providing for greatly extending the effective range of a single usage vehicle, such as in a missile.

The foregoing description is exemplary rather than defined by the limitations within. Many modifications and variations of the present invention are possible in light of the above teachings. The preferred embodiments of this invention have been disclosed, however, one of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. For that reason the following claims should be studied to determine the true scope and content of this invention.

What is claimed is:

1. A combined stage rotor blade for a turbofan engine comprising:

a first rotor blade portion which communicates airflow toward a fan bypass section of the turbofan; and

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a second rotor blade portion contiguous and at least partially transverse with said first rotor blade portion, said second rotor blade portion communicates airflow toward a core section of the turbofan.

2. The rotor blade as recited in claim 1, wherein said first blade portion extends substantially perpendicular to said second blade portion.

3. The rotor blade as recited in claim 1, wherein said first blade portion defines a first outer diameter and said second blade portion defines a second outer diameter, said first outer diameter greater than said second outer diameter.

4. The rotor blade as recited in claim 1, wherein said first blade portion communicates airflow overboard.

5. The rotor blade as recited in claim 1, wherein said second blade portion communicates airflow toward a combustor of the turbofan.

6. The rotor blade as recited in claim 1, wherein said second blade portion extends at least partially within the core section.

7. A turbofan engine comprising:

a fan bypass section;

a core section;

a shaft;

a first rotor blade portion mounted for rotation with said shaft, said first rotor blade portion to communicate airflow toward said fan bypass section; and

a second rotor blade portion contiguous and at least partially transverse with said first rotor blade portion, said second rotor blade portion mounted for rotation with said shaft to communicate airflow toward said core section.

8. The turbofan engine as recited in claim 7, wherein said second blade portion communicates airflow toward a combustor section.

9. The turbofan engine as recited in claim 7, wherein said second blade portion extends at least partially within said core section.

10. The turbofan engine as recited in claim 7, further comprising a second compressor wheel mounted to said shaft.

11. The turbofan engine as recited in claim 10, further comprising a turbine wheel mounted to said shaft downstream of said second compressor wheel.

12. The turbofan engine as recited in claim 7, wherein said first rotor blade portion and said second rotor blade portion form a combined stage rotor, said first rotor blade portion and said second rotor blade portion located adjacent a junction between a fan bypass duct of said fan bypass section and a core duct of said core section such that the combined stage rotor essentially spans said fan bypass section and said core section.

13. The turbofan engine as recited in claim 7, wherein said first rotor blade portion and said second rotor blade portion at least partially surround said junction.

14. The turbofan engine as recited in claim 13, wherein said first rotor blade portion extends at least partially into said fan bypass duct and said second blade portion extends at least partially into said core duct.

15. The turbofan engine as recited in claim 13, wherein said first blade portion extends substantially perpendicular to said second blade portion.

16. The turbofan engine as recited in claim 7, wherein said first rotor blade portion and said second rotor blade portion are located generally forward of said junction.

17. The turbofan engine as recited in claim 7, wherein said first rotor blade portion and said second rotor blade portion form a single L-shaped stage.

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**18.** A turbofan engine comprising:

a combined stage turbofan engine mounted for rotation about an axis of rotation, said combined stage turbofan engine rotor having a fan bypass rotor blade portion contiguous and at least partially transverse with a compressor rotor blade portion.

**19.** The turbofan engine as recited in claim **18**, further comprising a single shaft which mounts said combined stage rotor and a compressor mounted to said shaft downstream of said combined stage rotor.

**20.** The turbofan engine as recited in claim **19**, further comprising a turbine mounted to said shaft downstream of said compressor.

**21.** The turbofan engine as recited in claim **18**, further comprising a combustor section in communication with said compressor rotor blade portion such that said compressor rotor blade portion communicates airflow toward said combustor.

**22.** The turbofan engine as recited in claim **18**, wherein said fan bypass rotor blade portion and said compressor rotor blade portion form a single L-shaped rotor blade of said combined stage rotor which communicates with both a fan bypass section of the turbofan and a core section of the turbofan.

**23.** The turbofan engine as recited in claim **18**, wherein said fan bypass rotor blade portion and said compressor

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rotor blade portion are adjacent a junction between a fan bypass duct and a core duct.

**24.** The turbo fan engine as recited in claim **18**, wherein said fan bypass rotor blade portion is radial outward and forward of said compressor rotor blade portion relative said axis of rotation.

**25.** A combined stage rotor blade for a turbofan engine comprising:

a first rotor blade portion which communication airflow toward a fan bypass section of the turbofan; and

a second rotor blade portion contiguous with said first rotor blade portion, said second rotor blade portion communicates airflow toward a core section of the turbofan, said first blade portion extends substantially perpendicular to said second blade portion.

**26.** A turbofan engine comprising:

a fan rotor blade stage portion contiguous with a compressor rotor blade portion, said fan bypass rotor blade portion and said compressor rotor blade portion form a single L-shaped rotor blade which communicates with both a fan bypass section of the turbofan and a core section of the turbofan.

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