New Space Drive

Technology development for New Space cost efficient high performance drive

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Projektbeschreibung

Ausgangssituation, Probleme und Motivation
Die Raumfahrtindustrie steht zunehmend unter Kostendruck. Satelliten mit vergleichbarer Leistung sollen zu geringeren Kosten, oder leistungsstärkere Satelliten zu gleichen Kosten gebaut werden. Mechanismen und Antriebseinheiten als Teil dieser sind ein wesentlicher Kostentreiber von Satelliten, wobei der Kostendruck direkt an die Hersteller von Mechanismen weitergegeben wird. In diesem Projekt soll eine deutliche Kostenreduzierung dieser Antriebseinheiten durch einen New-Space-Ansatz erzielt werden. Dabei wird eine Kostenreduktion von 66 % bei Space Drives und eine Verkürzung der Lieferzeiten auf weniger als 3 Monate angestrebt. Die Antriebseinheiten sind nicht mehr als „Long Lead Items“ zu betrachten und müssen nicht vorbestellt werden. Damit wird ein standardisiertes Einkaufsverfahren ermöglicht, und die Antriebseinheiten müssen erst zu einem späteren Zeitpunkt in Entwicklungsprojekten finalisiert werden.

Ziele und Innovationsgehalt:
Das primäre, große Ziel dieses Projektes ist die Entwicklung einer New Space Antriebseinheit für den Raumfahrtsektor, die aufgrund ihres universellen Ansatzes für viele Einsätze geeignet ist. Die Anwendungen sind breit gefächert und umfassen operative Funktionen wie das Entfalten von Auslegern, Schutzschilden und Solarsegel, das präzise Ausrichten von Triebwerken und Antennen, die Neufokussierung optischer Instrumente und noch viele weitere. Der Betrieb soll unter den unwirtlichen Bedingungen auf Erd-Umlaufbahnen wie GEO, LEO und MEO, sowie im tiefen Weltall möglich sein.
Um alle gesteckten Anforderungen realisieren zu können, muss ein innovativer Ansatz gewählt werden. Dieser basiert auf neuen Design- und Produktionsmethoden und kombiniert 3D-Druck von Hochleistungskeramiken, Verwendung neuer Materialpaarungen für trockengeschmierte Verzahnungen, eine für die Materialpaarung ausgeklügelte Anpassung von Verzahnungstopologien, Nutzung von aufbereiteten Industriekugellagern zur Realisierung isotherm gelagerter Wellen und der Neuentwurf eines für diesen Antriebsstrang angepassten Hybridmotors mit reduzierter Schrittweite. Die Herausforderungen liegen in jeder einzelnen der eben beschriebenen anspruchsvollen Aufgaben.

Angestrebte Ergebnisse und Erkenntnisse:
Dieses Projekt beabsichtigt mit entsprechendem Entwicklungsaufwand und Know-how bestehende Hürden in der Raumfahrtantriebstechnik abzubauen. Grundsätzlich ist der Markt bereit, diese Innovationen anzunehmen und zu nutzen.

Die Integration neuer Technologien wie lithografischer 3D-Druck erlaubt es, präzise Keramikbauteile einfach und in großen Mengen kostengünstig herzustellen. Damit führt dieses Projekt mit dem verdichteten Wissen der Akteure zu einem Mehrwert für alle Konsortialpartner. Mit der zukünftigen Schaffung dieses Produkts wird der österreichische Markt für Raumfahrtzulieferer gestärkt, und neue Arbeitsplätze werden geschaffen, um eine effiziente Produktion dieser Komponenten zu gewährleisten.

Abstract

Initial situation, problems and motivation:
Space industry is under increasing cost pressure. Satellites with comparable performance are to be built at lower cost, or more powerful satellites are to be built at equal cost. These goals can only be achieved by reducing the cost of satellite equipment. Mechanisms are a significant cost driver of satellites, and the cost pressure is passed on to the mechanism manufacturers. They, in turn, are under pressure to leverage any tangible cost reduction potential. Drive units are one major cost component in mechanism production. For these, a significant reduction in cost through a new-space approach is to be investigated in the proposed project.
A 66% cost reduction in space drives and a reduction in delivery times from the current typical 10 months to less than 3 months are targeted. The drive units have no longer to be considered as "long lead items" and do not need to be ordered in advance. They can follow standardized purchasing procedures and can be specified later in development projects.

Goals and innovation:
The primary, major goal of this project is the development of a drive unit for the space sector, which can be used for many applications based on its universal approach. The areas of application are wide and include operations like deployment of booms, radiators and solar arrays, pointing tasks for thrusters and antennas, refocussing of optical instruments and many others, thus being able to operate in GEO, LEO, MEO and deep space environmental conditions.
To meet all these requirements within the constraint of a limited financial cost frame, an innovative approach shall be realized. This approach is based on new design and production methods, and combines 3D printing of high performance ceramics, use of new material pairings for dry lubricated gearing, sophisticated adaption of gearing topologies, use of affordable isothermal bearing technology incorporating refurbished industrial ball bearings, and the design of an adapted hybride motor at reduced step sizes. The challenges lie within each of the ambitious described tasks.

Desired results ad findings:
This project aims to break down existing hurdles in space drive technology. In principle, the market is ready to accept and use these innovations. However, it also takes development effort and development know-how to leave the existing paths and overcome it with technological innovations. The integration of new technologies such as lithographic 3D-printing, the possibility of manufacturing complicated ceramic components with sufficient precision, easily and in large quantities at low cost, with the condensed knowledge of the players leads to added value that affects the consortium partners involved. The expertise increases, and new technological territory is broken. With the creation of the product, the Austrian market for space suppliers will be strengthened, new jobs will be created in order to ensure lean production of these components.

Endberichtkurzfassung

It was demonstrated within the activity that a highly reducing gear for a high temperature range can be implemented to space standards. The major outcome was the reachable performance in terms of torque and efficiency for a given size of gear.

The high reduction allows low power consumption of the unit over a wide temperature range: the power consumption amounts to less than 4.5 W within a temperature range of -150°C to +150°C.

Analysis revealed that even with the high mass on the planetary cage which is typical for the Wolfrom type gear a first Eigen-frequency of >260 Hz can be reached.

Despite the targeted output torque could not be reached, the concept provides a solution for highly reducing gear applications in extreme temperature environment which can be beneficial for future science and commercial missions.

The following applications can be targeted:

- Cryogenic applications

- High temperature applications

- Applications with reduced thermal control for technical or for cost saving reasons

Highlights:

A new, highly efficient gearing geometry was developed based on insights from two PhD theses focused on minimizing engagement length during gear contact. This led to the use of a very small gear module, a steep pressure angle, and compact root and tip circle dimensions - all coordinated with the helix angle to optimize meshing efficiency. These design innovations required tailored milling tools and a redesigned CAD workflow, including custom 3D printing files for ceramic gears suited to the geometry.

Extensive long-term testing using the Pin-on-Disc (POD) method revealed a broad spectrum of material pairings, spanning both ceramic and metallic counterparts. Results showed significant variation in friction coefficients and wear performance across the combinations. Notably, one specific pairing demonstrated exceptional characteristics in minimizing friction and abrasion - marking a novel finding not previously explored within the space industry. This promising combination, the material combination of ZrO ceramic with Toughmet AT110 brass, is a very suited candidate for tribological contacts in space. This combination shows low wear and low friction and is not limited to be used in air or vacuum only but holds potential for wider applications beyond aerospace.

During the material manufacturing phase, ceramic components were successfully printed using stereolithography with the

CeraFab 7500 system (Lithoz). Multiple ceramic slurries - YSZ, alumina, and ATZ - were selected based on space-relevant mechanical and tribological demands. The process chain, including printing, debinding, and sintering, was optimized for accuracy and strength without major technical issues. Among the materials, YSZ displayed superior tribological performance, while alumina provided better post-sintering surface quality. Mechanical and microstructural testing confirmed material properties and density, although cleaning challenges and part deformation extended the overall production timeline.

An advanced manufacturing process chain was established to produce complex gears based on a Wolfrom gearbox architecture. This innovation enabled the creation of entirely new tooth profiles with customized pressure and helix angles, made possible by specialized carbide gear cutters. The associated milling machine was upgraded to meet demanding requirements, including precise angular positioning and a dividing head - resulting in metal gears with exceptional surface quality.
Remarkably, this fabrication approach is equally effective for ceramic components in their green state - prior to debinding and sintering - without requiring any modifications. The resulting surface roughness matches that of their metallic counterparts, making these ceramic gears highly suitable for implementation in gearbox systems.

Challenges that arose during the project:

A key production challenge emerged in machining the gears and toothed components: precise centering was essential to ensure consistent transmission behaviour and smooth gear operation. Achieving this required a complete re-evaluation of the holders used for both metal and ceramic blanks, aiming to minimize eccentricities. This optimization not only improved gear smoothness and transmission accuracy but also reduced peak stress on the components.

The production of ceramic 3D-printed gears presented a significant challenge, particularly with incomplete surface cleaning due to the pasty material used. As a result, the printed components were unsuitable for direct use after sintering without mechanical post-processing. A breakthrough emerged by machining the gear geometry during the green state of the ceramic blanks. This approach not only solved the issue but also marked a major innovation and a successful advancement in the process.

The brittleness observed in the 3D-printed and sintered ceramic components - resulting in fractures during testing and total gear failure under high loads - remains poorly understood. This outcome highlights the need for a detailed follow-up investigation aimed at identifying the underlying causes and developing an appropriate failure model to fully explain this behaviour.

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