HYBRID ROCKETS IN EDUCATIONAL PROGRAMS AT NAROM

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ABSTRACT

Norwegian Centre for Space Related Education (NAROM) has established a rocket program to stimulate the interest for science in general and to inspire young minds to space education, research and industry. This rocket program includes all from simple water rockets to larger scientific rocket campaigns. Hybrid rockets are a major part of this rocket program, and we will in this paper present two hybrid rocket motor demonstrations. We will also focus on how NAROM use hybrid rockets in educational programs and the educational advantages by using these demonstrations.

1. ABOUT NAROM

NAROM is a subsidiary company of Andøya Rocket Range (ARR), and was established in 2000 as a field station for space-related education. NAROM organize courses for students, teachers and others from primary school to university level. During the courses NAROM combine theory with workshops and use of instrumentation at the Range. The participants are living together with the lecturers in the hotel at ARR. This provides a positive educational environment. Fig.1 shows NAROMs location at ARR on Andøya, Norway.

NAROM is partly funded by the Norwegian government. A yearly state grant covers approximately 50\% of the costs. Other costs are covered by revenue from educational activities. NAROM has developed space educational material which is freely available to all on the Internet. The digital textbooks are illustrated with data from some of the instruments at the Range. In 2006 NAROM ran 69 courses on a number of subjects, with 1835 students participating. Examples of NAROM courses are Space physics, Space technology, European Space Camp, Nordic Teacher Space Camp, Earth observation, Environmental Physics. NAROM also has initiated and project management for the Norwegian student satellite program, ANSAT, which during a 5 years period will coordinate the building and launching of 4 student pico satellites.

NAROMs goals are:
- To ensure recruitment to space research, education and industry.
- To promote appreciation for the benefits of space activities.
- To stimulate the interest for science in general.

2. ROCKET PROGRAMS AT NAROM

NAROM has developed several rocket programs with different educational approaches and of different sizes. The rocket programs focuses on different rocket configurations, which combined or separate constitute an educational activity. The most common rocket configurations used in the rocket programs are water rockets, model rockets, hybrid rockets, student rockets and larger scientific sounding rockets.

Water Rockets

![Water Rockets](image1)

Student Rockets

![Student Rockets](image2)

Hypersonic Rockets

![Hypersonic Rockets](image3)

Figure 2. Different rocket configurations used in educational activities at NAROM

Water rockets are the least complicated rocket configuration, but still it is the most common used rocket at NAROM. The reasons for the popularity of water rockets besides its simplicity are its appeal to a large group of users at almost any age, and of course that this is one of the least expensive rocket experiments one can do.
Model rockets take it a step further from water rockets. The most important advantage with model rockets is the wide range of complexity, from simple ready-to-fly model rocket kits to challenging high skill level model rockets. This makes model rocket ideal for everything from classroom education to student activities at higher educations. Model rockets can also carry smaller payloads like altimeters, accelerometers or even cameras.

Student rockets can be described as a mix between a professional rocket and an educational rocket. With student rockets the participants also have to build parts of the payload instrumentation, make final assembly and testing of the payload, contribute in receiving of telemetry data and of course processing and analyzing data. In addition the students participate in the countdown and launch of the student rocket from ARR. More information about the student rocket program at NAROM is described in [1].

Scientific sounding rockets are seldom used exclusively for educational purposes, but sometimes student instruments are part of the payload. NAROM also use data and results from earlier sounding rocket campaigns from ARR in activities with an educational approach.

The different rocket programs at NAROM are most efficient when they are combined to form a student rocket course, in terms of feedback from the participant. Hybrid rocket motor demonstrations are usually included in all rocket activities at NAROM, but are also run as separate demonstrations. This will be described more in chapter 4. We see that these courses really inspire the participants and that these rocket activities are important contributors for NAROM achieving our goals.

3. HYBRID ROCKET MOTOR DEMONSTRATIONS

NAROM have in cooperation with Norwegian Rocket Technology (NRT) developed two different hybrid rocket motor demonstrations for use in educational activities. The major advantage with hybrid rocket motors is that the rocket motor contains no explosives. This makes it safe for students to participate in preparations and firing of the rocket motors. In the next chapter of this paper there is more information about the educational approach of the hybrid rocket motor demonstrations. This chapter will focus on a general description of the demonstrations.

3.1. The N₂O and Plexiglas hybrid rocket motor demonstration

The first hybrid rocket demonstration proves how simple a hybrid rocket motor could be made and provides a visual experience of the combustion. For this demonstration we use an Ø100mm Plexiglas (PMMA) tube as the fuel grain and combustion chamber, and N₂O, also known as laughing gas, as the oxidizer. A schematic overview of the demonstration is shown in Fig. 3.

The gas is fed to the combustion chamber through a gas hose. The pressure is regulated through a regulator (R21). An injector nozzle spreads the gas into the PMMA tube. Thus, the inner 100 mm of the tube is added with another Ø90 mm PMMA tube. In this way we are able to maintain a longer combustion. Inside the tube there is an igniter charge and an electrical squib attached to tube wall. When the regulator of the oxidizer gas bottle is open, the electrical squib fires the igniter which will start the combustion of the hybrid rocket motor. The transparency of the PMMA tube makes the combustion a visible experience. Fig. 4 shows the N₂O and PMMA hybrid rocket motor in action.
and a nozzle. To start the combustion we use an igniter in the same way as the Plexiglas motor. The polyethylene fuel grain has drilled 7 holes through it to increase the surface and regression rate. The complete fuel grain is made by attaching the polyethylene to a paper phenolic tube. Fig. 5 shows the fuel grain before and after a firing.

![Figure 5. Polyethylene fuel grain before (left) and after (right) a hybrid rocket motor firing](image)

The motor is placed on a wagon which pushes a load cell. There are also mounted 3 pressure transducers, placed in the combustion chamber, before the injector and on the gas tank. When the rocket motor is fired the generated thrust can be logged, together with the pressure variations from the gas bottle through the injector and in the combustion chamber. Fig. 6 shows a schematic overview of this hybrid rocket demonstration.

![Figure 6. Schematic overview for polyethylene and N₂O hybrid rocket motor](image)

This rocket motor is build with future improvements in mind. The load cell and pressure transmitters are industrial types and can handle a lot more loads and pressures than the motor generates as the system is today. The combustion chamber is also constructed in a way that makes it easy to expand. The expansion could for example be a longer fuel grain or an after burning chamber. Another improvement for the system as it is today could be to use a computer based control and acquisition system.

4. EDUCATIONAL APPROACH

4.1. Educational advantages for using hybrid rocket motor demonstrations

There are several reasons for why NAROM uses these hybrid rocket motor demonstrations in educational activities. The advantages are many:

- Hybrid rocket motors are safe. There are no explosives in the rocket motors. Thus, students can be allowed to get hands-on experience on the rocket motor.
- Hybrid rocket motors can be used for students/pupils from elementary to university level.
- With hybrid rocket motors the students can see how the theory of different science subjects works in “real life”.
- Running hybrid rocket motor demonstrations does not cost much money.
- Hybrid rocket motors are exciting and fun for the students.

4.2. Student involvement

As mentioned above, these hybrid rocket motors are almost completely safe to work on. This allows us to involve the students on the building, preparations and firing of the motors. This is of course supervised by the NAROM staff. The Plexiglas motor must be built from scratch, and it is so simple that even upper secondary school students could do it. The students can cut the Plexiglas and attach it to the injector nozzle. Fig. 7 shows students witch has completed the Plexiglas.

![Figure 7. Students have completed the Plexiglas](image)

The students can also assemble the Plexiglas to the gas and firing the motor. Only assembling of the igniter is done by the supervisors.

With the polyethylene hybrid rocket motor the students can do the preparations for firing the motor. First the students must insert a new fuel grain into the
this takes some time because there are quite many screws and bolts on the motor. During this activity the supervisor can attach the igniter. When the fuel grain is attached the students can prepare the gas and the solenoid valve. Before countdown and firing of the rocket the students have to prepare for logging data. The logger used have till today been an HIOKI data logger with 4 channels.

Figure 8. Students working on the polyethylene hybrid rocket motor

4.3. Hybrid demonstrations adapted to different levels of education

As mentioned earlier in this paper the hybrid rocket motor demonstrations could be adapted to different levels of education. For elementary pupils or teachers it is not necessary to know about all the technical details of the demonstrations. They neither need to know the equations of combustion principle and how they are derived. The important issue for these pupils and teachers are that this is what science subjects are about, and if they want to learn more they have to study subjects as mathematics, physics and chemistry.

For students the settings could be a bit more difficult. For the PMMA hybrid rocket motor demonstrations the students could do all the preparations and firing of the motor. With the polyethylene hybrid rocket motor the students could do analysis in addition. Together with other simple measurements the students can analyze the data and achieve more information about issues as oxidizer-fuel ratio, regression rate, total impulse and more.

5. FUTURE PLANS

NAROM want to continue to use these hybrid rocket motor demonstrations in the future, because of the success we have experienced with this concept so far. But further improvements are under considerations. We are in the near future planning to do the improvements of the existing hybrid rocket motor demonstrations which were mentioned in chapter 3 in this paper. But the natural step further for NAROMs hybrid rocket programme will be hybrid sounding rockets. NAROM have initiated a project for using hybrid rockets in education. Here we evaluate the possibilities in the Norwegian industry for building smaller hybrid sounding rockets for educational purposes. We are optimistic about this issue and if everything goes as we want, there could be a validation launch of these hybrid rockets in 2008.

6. SUMMARY

This paper has presented how NAROM use static firing of hybrid rocket motors in our educational activities. Two hybrid rocket motor demonstrations have been presented, with their technical details and educational advantages. Hybrid rocket motors are safe for students to work on and this makes it possible for the students to get hands-on experience on rocket motors. NAROM use hybrid rocket motors in education to inspire young minds for science, and will continuously make improvements for these hybrid activities at Andøya Rocket Range and Norway.

7. REFERENCES