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Basic Space Payload Fastener

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Abstract

A new basic space fastener has been developed and tested by the GSFC. The purposes of this fastener are to permit assembly and servicing in space by astronauts and/or robots and to facilitate qualification of payloads on earth prior to launch by saving time and money during the systems integration and component testing and qualification processes. The space fastener is a rework of the basic machine screw such that cross-threading is impossible, it is self-locking and will not work its way out during launch (vibration proof), it will not wear out despite repeated use, it occupies a small foot print which is comparable to its machine screw equivalent, and it provides force and exhibits strength comparable to its machine screw equivalent. Construction is ultra-simple and cost effective and the principle is applicable across the full range of screw sizes ranging from a #10 screw to 2.5 cm (1 in) or more. In this paper, the fastener principles of operation will be discussed along with test results and construction details. The new fastener also has considerable potential in the commercial sector. A few promising applications will be presented.

Introduction

A new basic space fastener has been developed and tested by the GSFC. The purposes of this fastener are to permit assembly and servicing in space by astronauts and/or robots and to facilitate qualification of payloads on earth prior to launch by saving time and money during the systems integration and component testing and qualification processes. This fastener proves that one of the recurring problems prohibiting cost effective servicing and assembly of small structures on orbit can be solved in a reasonably straight forward manner. The fastener problem has long been overlooked and underestimated. To perform servicing on orbit, it was essential that the fastener be resistant to cross-threading; either by astronauts whose hands must be covered by large gloves which are not optimal for fine assembly or by robotic or machine means which, in the current art, are even less so. Also, the fastener must be able to resist the vibrations inherent in launch both from the standpoint of the huge forces and impacts involved and in terms of the natural tendency of all screws to back out during vibrations. At the same time, the device must be nearly as simple, efficient, cost effective and compact as the common machine screw.

The Problem

The two main deficiencies of the classical machine screw are: 1) That it has a propensity to back-out during vibrations and 2) That it is easily cross-threaded by astronauts wearing gloves and even more so by current state-of-the-art robots.

The reason machine screws back out during vibrations is inherent in the basic helix of the screw thread. Experience and tests have repeatedly shown that a screw backs out

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because of the shearing, or side to side motion of the two members the screw is joining together. This motion creates a formidable counter torque on the screw helix which tends to back out the screw. Current preload spring washers such as wave spring washers and lock washers actually enhance the problem by maintaining screw helix contact with the nut helix even as the screw backs out.

The reason cross-threading of machine screws is such a problem for astronauts and robots in space is inherent both in terms of the clumsiness of the robots and the gloved astronauts and the fine threads of machine screws. The classical approach has been not to perform servicing. However, in instances where it must be performed, screw threads are made very coarse, so that they cannot be cross-threaded. Because this makes them back out easier under vibrations, a highly frictional set of mating cones is installed at the top of the male screw and the female member it screws into. However, the course thread means that very large torques are required to obtain relatively modest preload forces. The large friction forces associated with the mating cones further reduces the preload forces (or alternately, requires larger input torques). This is especially problematic when one is attempting to unfasten the screw on orbit. These very large holding frictional forces are very unpredictable, and even dangerous, on orbit. Accordingly, they require very large and powerful tools to provide an acceptable margin of safety.

Principles of Operation

The strategy of the new basic space fastener was two pronged [1]. On the one hand, it was decided to prevent cross-threading by leaving the nut attached to the machine thread at all times so as to permit large preload forces with modest preload torques and then to shape the outside of the nut such that it acts as a coarse fastening system whose sole purpose is to join the mating members together. This strategy involved shaping the hole into which the nut was to be inserted in such a way as to perform as part of the coarse fastening system. On the other hand, it was decided to prevent the screw from backing out under vibration by prohibiting relative motion between the screw and the nut. It was further decided to do this by bottoming the outside of the screw thread against the outer wall of the nut thread.

Figure 1 [2] shows pictures of the test hardware which worked following the strategy outlined above. Figure 2 [2] shows line drawings of the same device in a manner that is useful in illustrating how the device works.

To solve the problem of making the thread of the screw bottom against the outer wall of the nut thread, it is necessary to alter the nut thread so that it has flats on its outer thread. This, in turn, is accomplished by machining a few thousands of an inch off the thread die used to form the nut thread. This, however, leaves the screw in an interference fit with the nut. Accordingly, a split is cut in the nut and two thin spring sections are formed in the nut wall. Thus, the nut can expand around the screw and the screw threads can bottom on the outer wall of the nut thread. The nut also acts as a form of lock washer that preloads radially so that the lock washer function does not tend to aid in backing the screw out during launch vibrations.

It is clear from Figures 1 & 2, how the outside of the nut and the inside of the fixture into which the nut fits mutually, act together to form a coarse fastening system that cannot cross-thread. As the screw, with attached nut, is turned gently in a counterclockwise direction as it is inserted into the hole, the screw and nut drops down into the hole. Once down into the hole, the counterclockwise motion must stop because the nut is stopped by the end of the screw shaft. At this point, the screw is turned clockwise, the nut turns with it and positions itself so as to ensure the interference with the irregularly shaped hole necessary for fastening. The nut then travels upwards to perform the preload and fastening functions. The unfastening process has the reverse sequence of that involved in fastening.

Hardware and Test Results

Test results are summarized below [2]. As can be easily deduced from the data, the tests were highly successful against a very difficult standard, MIL-STD-1312-7A (10/19/84), Method 7. Three evaluations of the concept were developed during a Phase I SBIR performed by Honeybee Robotics, Inc. The third evolution is the definitive one to date. It was a miniaturized version, based on a #10 machine screw. The test breadboard was preloaded with values of 6.8 N•m (5 ft•lbf), 20.3 N•m (15 ft•lbf) and 47.5 N•m (35 ft•lbf). In each case the system was subjected to vibration in accordance with the above mentioned MIL-STD and in each case it passed the entire test with no measurable loss of preload. In comparison with Spiralock, used in Shuttle Engines for vibration resistance, the Basic Payload Fastener is equally vibration resistant; but will undoubtedly prove to produce a significantly larger preload force for the same input torque with much less radial loading and wear. This is because the Basic Space Fastener loads only lightly on its outer screw diameter and more heavily on its upper screw surface (in the classic machine screw manner), where as, the Spiralock [3] loads heavily on its outer screw diameter. Also, Spiralock is vulnerable to cross-threading so is not a serious candidate for on orbit servicing by astronauts or robots.

The Ramifications of The Solution - NASA and Industrial

This fastener has the potential to become the standard space fastener for nearly all NASA's space operations. The device is essentially immune to vibrations, is resistant to wear and so can be reused many times without degradation of performance, and provides a strong preload force for a modest input torque. It can self-align and fasten despite significant initial errors in alignment, without cross-threading. Therefore it is suitable for use by robots or astronauts for on orbit replacement missions. The commercial potential is enormous. There are many examples such as aircraft component fasteners, engine mounting bolts, bolts in motorcycles, automobiles, military tanks, tracked and wheeled vehicles, and lug nuts on automobile wheels. Any application involving screws and nuts can be performed using this system.

Development Plans

Development plans center mainly on simplifying the device, for remaking and testing it using the materials and conditions that it must employ in order to be used in the earth orbit/space environment and making it more cost effective for NASA needs. In addition to this, the optimum geometry will be revisited, and robotic operations will be taken into consideration. This will involve considerably more detailed and extensive analysis and testing and modifications than performed thus far. Also, the enormous potential and requirements of industry will be kept in mind.

Summary/Conclusions

A promising and innovative general usage space fastener has been proven in concept to the very difficult standard of MIL-STD-1312-7A (10/19/84), Method 7. This fastener has the potential to become the standard space fastener for nearly all NASA space operations. The device is essentially immune to vibrations, is resistant to wear and so can be reused many times without degradation of performance, and provides a strong preload force for a modest input torque. It can self-align and fasten despite significant initial errors in alignment without cross-threading, thus being suitable for use by robots or astronauts. The commercial potential is enormous. There are many examples such as aircraft component fasteners engine mounting bolts, bolts in motorcycles, automobiles, military tanks, tracked and wheeled vehicles, and lug nuts on automobile wheels. Any application involving screws and nuts can be performed using this system. Future work will concentrate on more extensive and thorough testing, analysis and development to simplify and make this device even more cost effective and useful.

References

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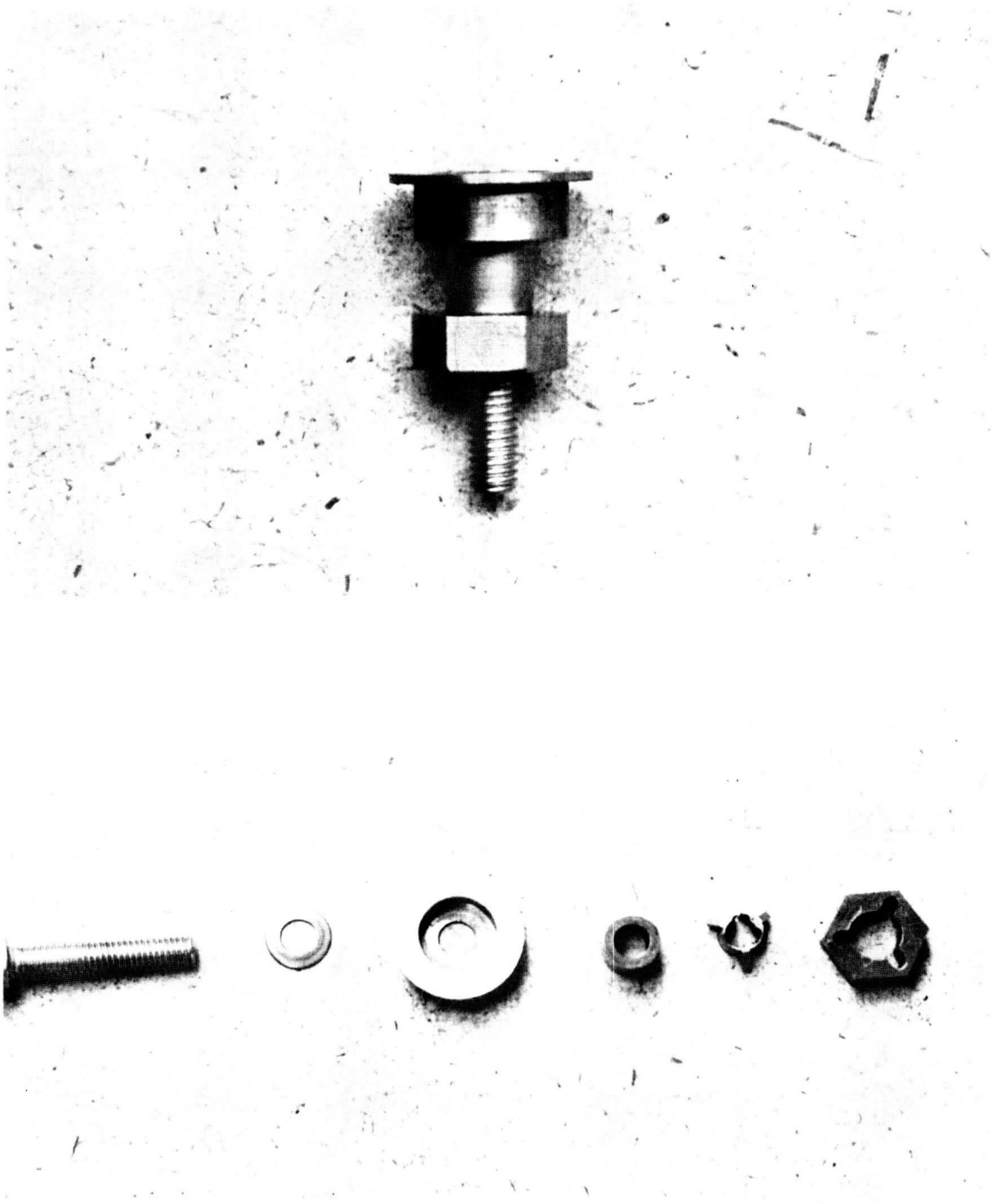

Figure 1

Phase 1 #10 fastener. Top, assembled system, and below, system elements. The split buttress locknut is second from right.

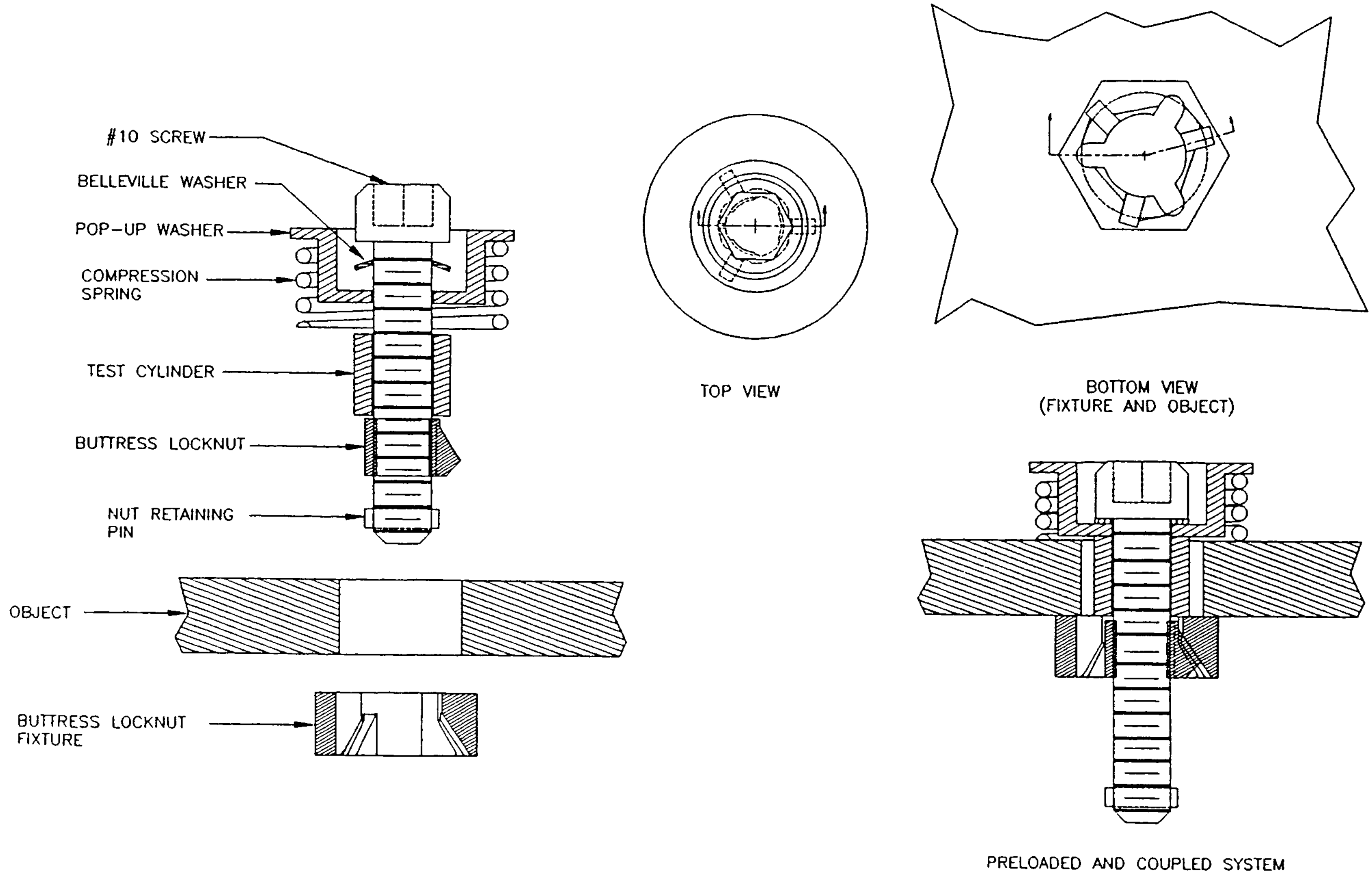

FIGURE 8: EVA/ROBOTIC COMPATIBLE PAYLOAD FASTENER BREADBOARD 3 TEST CONFIGURATION.