Design of Multifunctional Air Transportable Ground Support Trolley

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Abstract

Aircrafts have very limited choices with respect to a ready supply of electricity. Light, general-aviation aircraft do not have the luxury of onboard Auxiliary Power Unit (APU) like most turbine engine aircraft. In early days of aviation, aircrafts did not have storage batteries to run a starter, so the pilot had to turn the propeller by hand to get the engine start. Air motion within the intake manifold is one of the important factors, which governs the performance of an engine. The objective of Ground Support Trolley is to meet the perceived requirement of a multipurpose vehicle, which on a mobile platform would meet all the requirements of 1st to 4th line servicing.

The product is designed considering the ergonomic issues and performing the usability tests for the layout of the control panel. Also, the sources of heat generation are analyzed and accordingly the vents are designed. All concepts were derived on the basis of functional requirements and usability criteria during maintenance of the product. The final concept is selected using weighted ranking method. A physical model of the selected concept is also developed with a scale of 1:5.

The product provides quick access to the internal parts and hence is designed for the ease of maintenance. Thus, it reduces breakdown time. The technology is compacted and designed to make the product Air Transportable by the transport aircraft Antonov An-32 and suits the service requirements of helicopters (Mi-8, M-17, Mi-24, Mi-35) and fighter planes (Mig-21, Mig-25, Mig-27, Mig-29, Su-30).

Key Words: Air Transportable, Ground Support, Mobile Platform, Electric Power, Multifunctional.

Nomenclature

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Unit</th>
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<tbody>
<tr>
<td>H</td>
<td>Height, mm</td>
<td></td>
</tr>
<tr>
<td>f</td>
<td>Frequency, Hz</td>
<td></td>
</tr>
<tr>
<td>v</td>
<td>Voltage, v</td>
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Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AC</td>
<td>Alternating Current</td>
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<tr>
<td>APU</td>
<td>Auxiliary Power Unit</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>GPU</td>
<td>Ground Power Unit</td>
</tr>
<tr>
<td>GST</td>
<td>Ground Support Trolley</td>
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<tr>
<td>PDS</td>
<td>Product Design Specifications</td>
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</table>

1. INTRODUCTION

Histories of Industrial design tend to highlight the aviation/aerospace arena as prototypical example importance in industrial design. [1]

In aviation, “aircraft ground handling” defines the servicing of an aircraft while it is on the ground and (usually) parked at a terminal gate of an airport. It addresses many service requirements of an aircraft between the time it arrives at a terminal gate and the time it departs on its next flight. The aviation industry is uncompromising when it comes to the reliability of its aircraft as planes must stay in the air all of the time. It is just as demanding when it comes to performance, and over the past 30 years aircraft have become quieter, more fuel efficient and easier to operate. Speed, efficiency, and accuracy are important in ground handling services in order to minimize the “Turnaround time” (the time during which the aircraft must remain parked at the gate). Unfortunately when it comes to Ground Power Units (also called power carts), there have been few technological advances in recent years. Ground crew and maintenance staff still labors with power carts that are unreliable, noisy and hard to operate. When it comes to the bottom line, Ground Power Units (GPU) save their operators money, with less maintenance staff required, lower fuel bills, shorter set up times and less delayed flights due to unreliable Ground Power Unit. GPU is a ground based source of power. It is applied in order to shut down the Auxiliary Power Unit (APU) on the aircraft and thereby reduce the noise, the air pollution, and the maintenance of the APU. GPU is a mobile vehicle which is mounted with an enclosure. Within the enclosure are a number of subsystems, each of which provides a service required by a stationary aircraft for servicing and diagnostic testing prior to flight. Such services include electrical power, hydraulic power, engine-start capability (bleed-air), nitrogen to inflate struts and operate power tools and conditioned air (hot or cold) for the aircraft's equipment recesses or interior. The control, status, configuration, and automation of all of the subsystems contained within the enclosure are consolidated under computer control.

Facilities provided by the airport are readily available for the civil aviation aircrafts. But if we consider it for the Air Force Fighters and Helicopters where the base keeps on changing, where the need of power is met directly by the Auxiliary Power Unit (APU) or by the batteries integrated in the aircraft. Else if ground servicing is really required, the ground service equipments are transported by land transportation.

There is a need to design a multifunctional vehicle mounted platform that can be utilized for hydraulic, pneumatic, electrical servicing still should be as compact that it can be transported by a transport aircraft. [2]

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1.1 Applications of GPU

Ground power is recommended for all aircraft regardless of their size. Ground power should be utilised both during starting and servicing of the aircraft.

Using ground power while starting aircraft: While an aircraft’s battery is capable of starting the engine or auxiliary power unit (APU), this function is not recommended on a recurring basis. The starting of an engine or APU puts an enormous strain on a battery and as such, shortens the life of the battery. Furthermore, if the battery is not sufficiently charged after starting, the battery will slowly deteriorate and may eventually fail. Perhaps most importantly, starting an engine with a less than fully charged battery may cause unnecessary engine wear and even damage. Hence, a GPU is a preferred choice for starting of an aircraft.

Using ground power while servicing aircraft: Aircraft batteries are not designed to fully discharged and then recharged on a recurring basis. Using the battery while servicing the aircraft may lead to an over-discharged battery that in turn, may lead to the battery being over-charged during the recharging process. Such over-discharging and corresponding over-charging may damage the battery beyond repair. Therefore, a GPU is preferred during the ground service operations.

The use of ground power also translates into huge savings since the power can be converted on the ground much cheaper and much more efficient than by burning jet-fuel on the aircraft. The CFO of SpiceJet says “We are using more of the ground power unit (GPU) technique as compared to auxiliary power unit (APU) to increase efficiency,” as revealed in The Economic Times newspaper [3]. GPU provides on ground electrical aircraft power. APU is a device on a vehicle whose purpose is to provide energy for functions other than propulsion.

2. ISSUES WITH EXISTING DESIGN

The existing designs are studied in order to check the size and dimensions and also to identify the issues associated with them to be transported by transport aircraft. The complete service equipments available are huge in size and the modular equipments available are compact but cannot meet all the perceived service requirements on a single platform. Even air transport of multiple modular equipments is a cumbersome job. It can be observed in Fig.1 that all the body designs are just a shell covered over the internal parts.
The displays have been grouped together at the upper side of the control panel and all the controls at the bottom side. It’s logical that when you are operating the controls the vision on the displays is not obstructed by our hands. The panel is grouped into respective families of Engine Inhibition System, 400 Hz AC Panel and 28.5v DC Panel. Fig. 4 shows a clear illustration of the layout of the control panel.

4. USABILITY TEST

The ergonomics of control panel is an important aspect for the operator’s ease of use. As the height of the GST is constrained to be at 1060 mm, the angle at which the control panel has to be fixed will be among one of the critical factors of design. Accordingly a dummy control panel design was developed and was fabricated using bamboo and plywood (Fig. 5) on which the Usability was performed. It was tested for 20 people to analyse the ease of usage. Test as carried out for every 10° ranging from 0° to 90° for the usability of a dummy control panel. The results are listed in Table 1.

<table>
<thead>
<tr>
<th>Angle</th>
<th>Difficult</th>
<th>Moderately Easy</th>
<th>Easy</th>
</tr>
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<tbody>
<tr>
<td>0°</td>
<td>20</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10°</td>
<td>20</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>20°</td>
<td>19</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>30°</td>
<td>17</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>40°</td>
<td>10</td>
<td>9</td>
<td>1</td>
</tr>
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<td>50°</td>
<td>1</td>
<td>9</td>
<td>10</td>
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<td>60°</td>
<td>-</td>
<td>1</td>
<td>19</td>
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<td>70°</td>
<td>2</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>80°</td>
<td>18</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>90°</td>
<td>20</td>
<td>-</td>
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</table>

The usability test performed suggests that at a height of 1060 mm, the control panel should be placed at an angle inclined at 60° with reference to the ground.

5. PRODUCT DESIGN SPECIFICATIONS

A Product Design Specification (PDS) is a document, which sets out in detail what exactly will be required out of a product, before it is designed. It also helps users, to know how efficient is its performance and reliable is the product. A PDS is therefore also an analysis of what the market will demand.

6. HEAT GENERATION

There are various sources that generate heat. The following sources have been identified (Fig 6) that can cause overheating of the equipment:
- Engine Fan: An outlet where the heat produced is forced out.
- Gear Cluster: Continuous friction generates heat.
- Alternator: Magnetic field generates heat.

The issue of overheating can be dealt by proper design of vents.

7. CONCEPT GENERATION

A product concept is an approximate description of the technology, working principles, and form of the product. It is a concise description of how the product will satisfy customer needs. Concept generation is relatively inexpensive and can be done quickly in comparison to the development process so that there is little excuse for lack of diligence and care in executing a sound concept generation methodology.
Various idea generation tools like Mind Mapping (Fig. 7), Morphological analysis (Fig.8) [5] and TRIZ have been explored before the generation of concepts.

**Fig. 8 Morphological Analysis**

### 7.1 Concept 1

Concept 1 (Fig. 9) is developed on the basis of functional requirements and usability studies. The concept provides an envelope to the equipment. Also, provision is made for dummy panels so that the modular sub-system can be easily replaced with the new one, as the use of a particular sub-system depends on the type of aircraft.

### 7.2 Concept 2

Concept 2 (Fig. 10) is also developed on the similar lines of that of Concept 1. This concept too has the provision made for dummy panels so that the modular sub-system can be easily replaced with the new one. The only design change is in the shape where a channel is provided to incorporate the panel wires properly.

### 7.3 Concept 3

Concept 3 (Fig. 11) is developed in order to induce aesthetics. A large single panel door is provided, which helps to access the internal parts quickly during the time of equipment maintenance or during equipment breakdown. The provision for dummy panel is removed and is designed such that a single panel should meet the need.
7.4 Concept 4

Concept 4 (Fig. 12) is designed to provide a rugged look to the product. The top surface having the vent holes is covered by a protective roof that helps to keep out the rain water. Two panel doors are provided of which one helps to access the engine and the other helps to access the alternators.

8. CONCEPT SELECTION & DETAILING

The concept selection is made by using the Weighted Ranking Method. The Weight factor is determined using the objective tree for Weight factors. The nomenclature (Fig.14) and details (Fig.15) of the selected concept are shown below:

7.5 Concept 5

Concept 5 (Fig. 13) is designed to provide a simple, function based look to the product. The manufacturing cost of such design is always low. The top surface having the vent holes is covered by a protective roof that helps to keep out the rain water. Further, two doors are provided which are directly supported on rubber beads.

9. DESIGN OF VENTS

The sources of heat generation have been analysed to solve this issue, provision for proper ventilation is provided in the design. Forced ventilation as well as cooling is also
provided wherever needed. The flow of heat through the vents is represented in the Fig.16.

10. WORKING PROCESS

The Ground Power Unit functions the same as any diesel driven generating set. The major functional parts are represented in Fig17. An exciter winding provides power to the exciter rotor which is rectified to DC via a rotating diode assembly. The DC is then applied to the main rotor windings, which provides a rotating magnetic field to induce current into the main stator windings. The output from the main stator windings is the generator output and is 3-phase, 4-wire. The amount of voltage is dependent upon the winding design and the amount of excitation voltage applied. The output frequency is determined by the rotor speed (engine rpm) and the number of poles in the winding.

The generator output is controlled by an output contactor, operated by a set of push buttons. The output contactor is usually interlocked with several safety features from the generator's own condition monitoring and the aircraft which is designed to protect the operators and equipment. The trailing lead is fitted with a standard aircraft connector for the type of voltage and is connected to the aircrafts input receptacle before power is applied. The aircraft then samples the condition of the power before it is connected to the aircraft bus system.

11. PRODUCT ILLUSTRATIONS

These illustrations act as the source of communication for everyone who is associated with the product and also the probability of communication errors will thus be reduced. These pictures act as self explanatory medium of communication. Some of the rendered illustrations are represented in Fig.18, Fig.19, Fig.20, and Fig.21.

Product Illustrations provide a clear view of:

- The size,
- The environment in which the product will be used,
- The working of product,
- Relative comparison with existing products etc.

12. MOCKUP MODEL

The physical model mock up model is built with a scale of 1:5. Sun Board is the material used for fabrication process that involves internal parts as well as external body. The internal parts are painted with chrome.

13. CONCLUSIONS

The product provides quick access to the internal parts and hence is designed for the ease of maintenance. Thus, it reduces breakdown time. The technology is compacted and designed to make the product Air Transportable by the transport aircraft Antonov An-32 and suits the service.
requirements of helicopters (Mi-8, Mi-17, Mi-24, Mi-35) and fighter planes (Mig-21, Mig-25, Mig-27, Mig-29, Su-30).

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