A PROJECT REPORT

ON

"DESIGN & ANALYSIS OF CONTROLLED FALL DEVICE FOR EMERGENCY RESCUE "

Submitted by

16ME06,16ME17,16ME45,16ME59

In partial fulfillment for the award of the Degree

Of

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IN

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UNDER THE GUIDANCE

OF

PROF.SAAD SHAIKH

DEPARTMENT OF MECHANICAL ENGINEERING

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APPROVAL OF DISSERTATION

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CHAPTER-I 1. INTRODUCTION

Due to many factors including increase in population, coupled with limited land mass, architects have moved to design structures with minimal footprint, but maximum use. In turn, this has meant the structures have grown taller, transforming the skyline of cities, towns and villages as well as the industrial landscape. This trend has increased the risks associated with personnel rescue or evacuation from structures in an emergency. At first the solution was one of adding fixed structures either within or external to the main structure, such as fire escapes or stair wells. In the more recent past, over the last few decades, there has been a realization that alternative options need to be explored and developed to meet the challenges of modern living and structures. This has created a demand for equipment and systems that can either mass evacuate or single evacuate persons to safety, reducing the risk of injury or death. This additionally has resulted in a requirement and need to research methods and types of personal evacuation designs and a method to escape quickly and safely with minimal knowledge or training. The challenge for engineers is to develop equipment that is not reliant upon external power, is lightweight, easily transported and able to be retrofitted. Working in multi- discipline teams in order to gain the other perspectives on the problem such as the type of body device or harness to prevent injury due to suspension and being able to cope with physical disability. The starting point came from winch, machine braking and clutch systems linked with mountain climbing techniques. This continues to develop and through research and design the need to provide better insight and data to develop safer equipment. Until now, developing a personal descent device from structures meant reliance upon data or experience gathered from research, often not completely relevant to the subject matter. There is an overwhelming need to obtain more information and data and to present it in such a format that designs can be developed more easily and based on informative data and models. The dearth of 9information and configuration models, has resulted in designs which are usually bulky or over engineered, the problem being made worse by the lack of representable test data or the ability to easily test descenders in a laboratory due to a lack of sufficient descent height and other restrictions.

In studies SATRA (Shoe & Allied Trade Research Association -UK notified body) who are tasked with testing any descender devices to comply with the European standards, they admit that they have no method or equipment to test descenders. As a result, descent tests to the standards for this research were set up and performed with an in house order to gain experience on descent devices and how they actually perform. It is desirable to develop a descent controller that can operate under a variety of conditions easily, where the descent velocity is controlled in order to prevent injury, but would be sufficiently quick so as to take the user away from the structure in a controlled manner without further risks associated with prolonged suspension. The risks could be due to trauma or external influences such as explosions or fire balls. Consideration must be given to the fact that the person may be physically disabled or injured and may not be able to offer any assistance in the descent. These factors and others have to be considered in arriving at a solution. The environment is also relevant, so consideration must be given to the area towards which the person is descending. It may also be desirable to stop the person reaching the ultimate landing or entry position if that point presents further danger from obstacles that might injure the person. The intention is to have a design that is automatic and requires no training so that in the event of a requirement to evacuate quickly the evacuee can simply enter the system and escape or be able to operate it for others, basic set up as shown in fig 1.1. Survival from a height depends upon many factors including the height itself, but also the reason for evacuation. It is, therefore, imperative that options are controlled and that the design has been proven both through theory and practice for good repeatability and whilst in use in a panic situation. A requirement for functionality is to control the descent speeds, whilst covering as large a range of descent masses as possible over the maximum distance without relying on extrapolation of data caused by its lack of data, inadequate theory or the ability to test the mechanisms over long distances. The descent speed must be such that when the person reaches the ground level he is not travelling at excessive velocity causing injury might, but not slow enough that the person is exposed to secondary hazards such as suspension trauma, building collapse or other hazards. As the height increases, then the suspension time and that for evacuation become more relevant. Trials conducted by the United States of America military into different harnesses showed that the onset of discomfort and potential risk caused by suspension means that the time suspended must be kept to a minimum, if secondary issues are to be avoided (Brinkley,JW, 1991).

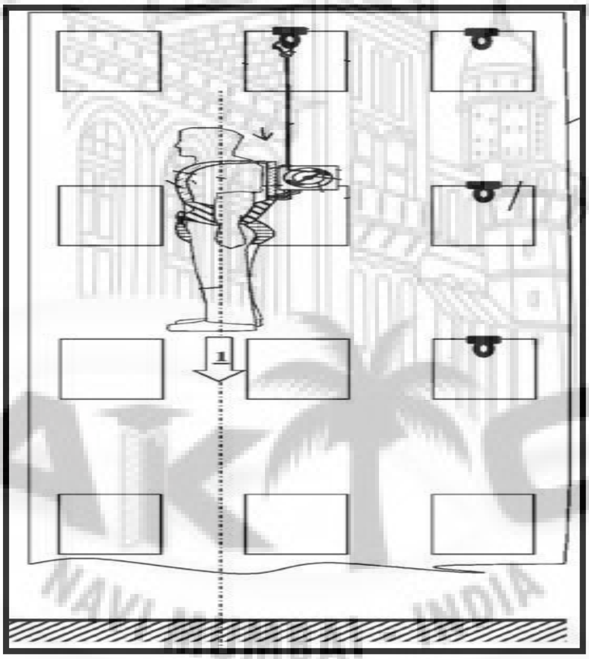


Fig.1.1 Descent controller in use

1.1 Problem Statement

The aim of this study is to explore possible design solutions to be applied for developing a personal evacuation device. In this context, a number of brake mechanisms have been modelled together with the selection of a suitable lifeline in order to create several scenarios of design to protect the user in the case of an emergency evacuation. This work involves creating test rigs in order to test and develop feasible solutions and to develop theoretical models against which the designs can be evaluated in order to provide engineers in the future with both testing and theory to help in design and development of descent control systems. There are some leading development company in the field of height safety world- wide and the development of height safety equipment for a number of markets. The work involved the design, prototyping, field testing and laboratory testing of potential technical solutions.

1.2 Objectives

a. A major element of a descent control system is the lifeline which must be compact, but must also meet environmental or disaster criteria. Thus, the first objective of the research programme described in this report is to select the lifeline.

b. In selecting the lifeline the next issue to be considered is the method of termination in order to again meet the environmental or disaster criteria. Thus, the second objective of the research programme described in this report is to develop the termination. The termination specifically relates to the sewing or mechanical provision of attachment to the evacuee and the device, as an example mechanical termination may be achieved by swaging.

c. The prime aim of any descent controller is to control the descent of persons in such a way that they escape in a timely manner, irrespective of their weight or the height of descent. Hence, the third objective is to develop mechanisms that would control the descent speed.

d. The descent controller has to operate over prolonged periods with constant speed with different masses. Extended tests are required to achieve this objective which is to ascertain how a solution performs in practice.

e. The fifth objective is to develop the theory to be able to predict the performance of the designs.

f. The objective is to see if the design solution can self-regulate its speed such that engineers can predict speed of descent against the gear ratio, thus enabling a larger unit to be constructed which would allow faster initial descent, but would slow the person down as the lifeline is paid out by the device affecting the gearing between the lifeline and the brake.

g. This is considered of interest in light of the ever increasing heights of structures and the time taken to evacuate from higher levels to the ground level.

1.3 Scope:

Personal evacuation and mass evacuation systems are predicted to be fundamental consideration for buildings and structures in the future. This is due in part to the demand for higher rise accommodation and work areas caused by land shortage and cost implications. This is driving the need for more solutions to be developed for descent systems. In addition, the advent of high profile terrorism, now considered a fact of modern living, will move forward the use and research of descent devices and systems as engineers of the future work on the problems associated with evacuation from height. The next stage in the development of the personal descent controller and the basis of future work is to investigate how mass evacuation is achieved using the brake mechanisms and lifelines developed here, including the use of cartridges that can be used to effect multiple descents. Future work would also include alternative braking methods with the descent controlled by hydraulics or pneumatics. Work on the position of strong anchorage points on the structure for evacuation, in addition to the use of lift shafts or blow out windows would form part of future work. This would integrate descenders with other equipment such as smoke hoods or guided escape methods. This work would allow for the inclusion in new technology, which presents new demands, such as wind farms, leading to an expanded scope for future work.

1.4 Methodology

In order to meet the aim and objectives of this project, the following methodology of work has been followed:

- Initial studies
- Conceptual design.
- Design consideration.
- CAD modeling.
- CAE analysis. .

Initial studies:- This involved a literature search identifying key incidents and International standards.

- Research into high profile incidents in order to identify major issues in personal evacuation. This was obtained from publications, an internet search and from direct contact with those who operate in the Industry, including in construction and rescue.
- Research into International standards which are applied to descent control devices and systems. This is obtained from direct participation representing the IMech E on the standards association
- Research and extensive review into products that are available and may soon be available. This was obtained by attending conferences and trade fairs in Europe and North America and by internet search.

Concept and performance phase:-

This phase involved the main body of work, leading up to the completion of the research project. In this phase, several approaches were investigated for the lifeline. This included construction, as well as material in order to meet the aims and objectives of the research. Several designs were investigated and samples prepared and tested. The derived data was then studied and used in the development of the ongoing concepts. The descent control mechanisms were next to be conceptually developed. Following on from lifeline selections, the mechanical functions were considered. Several designs were developed, with prototypes built for testing and evaluation. As with the lifeline, the test data was then analysed in order to develop potential solutions. Many aspects were considered during this phase, including weight, compactness, endurance and repeatability, as well material selection proving useful in the ongoing development of several design solutions. Test rigs were developed and built to carry out performance tests on a number of functions regarding the lifeline and the mechanical designs. The rigs which were built enabled tests to be carried out under both static and dynamic conditions.

The main body of work can be broken down as follows:-

An investigation and development of possible solutions for the lifeline was performed. Criteria such as type, size and construction were considered taking into account environmental considerations. Testing was carried out using test rigs developed as part of the study in order to evaluate the lifeline and the effects of different terminations Special fixtures were developed to terminate the samples. Prototype testing was carried out on rope, wire rope and webbing lifelines, evaluation of those results was used in the ongoing device development. A study into the various options and methods of creating a controlled descent were performed. This involved making a number of prototypes and testing them on purpose-built test rigs to determine their dynamic performance.

The data from this test was then used to develop the device there were a number of factors considered in the development, including but not limited to the control of descent speed. For example, a user would not be injured by excessive speed or injured by negligible speed (suspension trauma or environmental), the lifeline has to be capable of being deployed safely and capable of withstanding adverse environmental conditions that may occur such as heat or fire. Material selection and lifeline type played an important role in the development process in order to meet the key aims. A test rig was constructed in order to determine torque, descent speed against drop mass and further developed in order to evaluate the performance of the designs. The test data was compared with theoretical analysis and external testing at a test site, as well as at the purpose-built dynamic test tower.

The activation of the descent control design was also considered as part of the development from permanent engagement to motion activation, and from manual control to automatic. Several test pieces were manufactured and tested using the test facilities developed. Tests were also conducted. The final objective was to build a prototype and develop a test rig to test the effects of a varying torque on the descent speed for a brake design in a dynamic condition. The data was analysed and compared with theory for inclusion in the design.

There is a dearth of test facilities and capability currently which can inhibit development. There is a firm anticipation that the results and experience gained from this work will facilitate better understanding of test procedures, test methods for descent control mechanisms and lifelines.

The results, conclusions and findings can be an available source of information to be used by designers and engineers in the future when developing or considering descent control devices or used by architects in consideration of the escape options in future structural designs.

LITERATURE SURVEY

SR. NO	AUTHOR	TITLE	YEAR
1	George Darnell, P.O, Box 589, Bokeelia, Fla. 33922; John E. Darnell, 2026 Garrison St., walla Walla, Wash. 99362	CONTROLLED DESCENT DEVICE US- - 5,056,619	1991
2	Pjilip H. Schreiber, Denver, CO (US); Timothy W. Ecker, Thronton, CO (US);	CONTROLLED DESCENT DEVICE US 6,810,997 B2	Nov. 2, 2004
3	John M. Donaldson, Grosse Pointe Park; Donn E. Vidosh, Bloomfield Hills; Lars G. Karlsson, Framington Hills; all of Mich	EMERGENCY DESCENT DEVICE US- -4,457,400	Jul. 3, 1984
4	Scott C. Casebolt	SELF-RESCUESAFETY DEVICE US 8.245,817 B2	Aug. 21, 2012
5	ASTM International	Standard Specification for High-Rise Building External Evacuation Controlled Descent Devices 1	2007

CHAPTER-II

2. LITERATURE REVIEW

In the following chapter details will be given of high profile incidents that have occurred in recent times. These are selected to further understand and show the need to carry out research into this important subject. Later, there is an overview of the current International standards and test procedures which are still evolving for this type of development and to assist in understanding of the subject and explain why and how tests are carried out some literature and technical information relating to descent control was found during the various searches carried out and this is discussed. In the public Inquiry into the Piper Alpha Disaster, Cullen, The Honorable Lord (1990) made reference to the need to have secondary methods of evacuation, referencing directly descent control devices as a solution for workers in the future. Even prior to the Piper Alpha disaster, a production platform operating in the Enchova field, Brazil on the 16th August 1984 had a blowout, followed by an explosion and fire. Two personnel died during the evacuation, 36 killed when the lifeboat lowering mechanism failed and the occupants fell with the lifeboat some 10 - 20 m into the sea. A further 6 workers were killed when they jumped from a height of 30 and 40 m into the sea. The World Trade Centre Towers 1 and 2 was the subject of a terrorist attack on September 11th 2001 resulting in the death of 2753 people. Most high rise structures, i.e above 23 m have built in redundant safety features and mass evacuation of this type of structure is relatively rare so little is known about how quickly one can, or need to evacuate the building. In an explosion or any fire the main method of evacuation are the stair wells or fire escape with all lifts immobilized or automatically returned to ground level. Levels above 35 m are problematic to reach using conventional fire fighter equipment and techniques such as ladders or extending

2.1 Fall Related Incidents at Workplace

In the workplace the Health and safety Executive publish statistics relating to incidents at work where injuries or fatalities have been recorded. Descent controllers, in many instances could help reduce the number of fatalities caused by falling from a height, as well as reducing the number of serious injuries. The problem is identified which gives the mortality rate from falling. This does not include any data on mortalities caused by a failure to evacuate and being trapped by structures, fire or explosions.

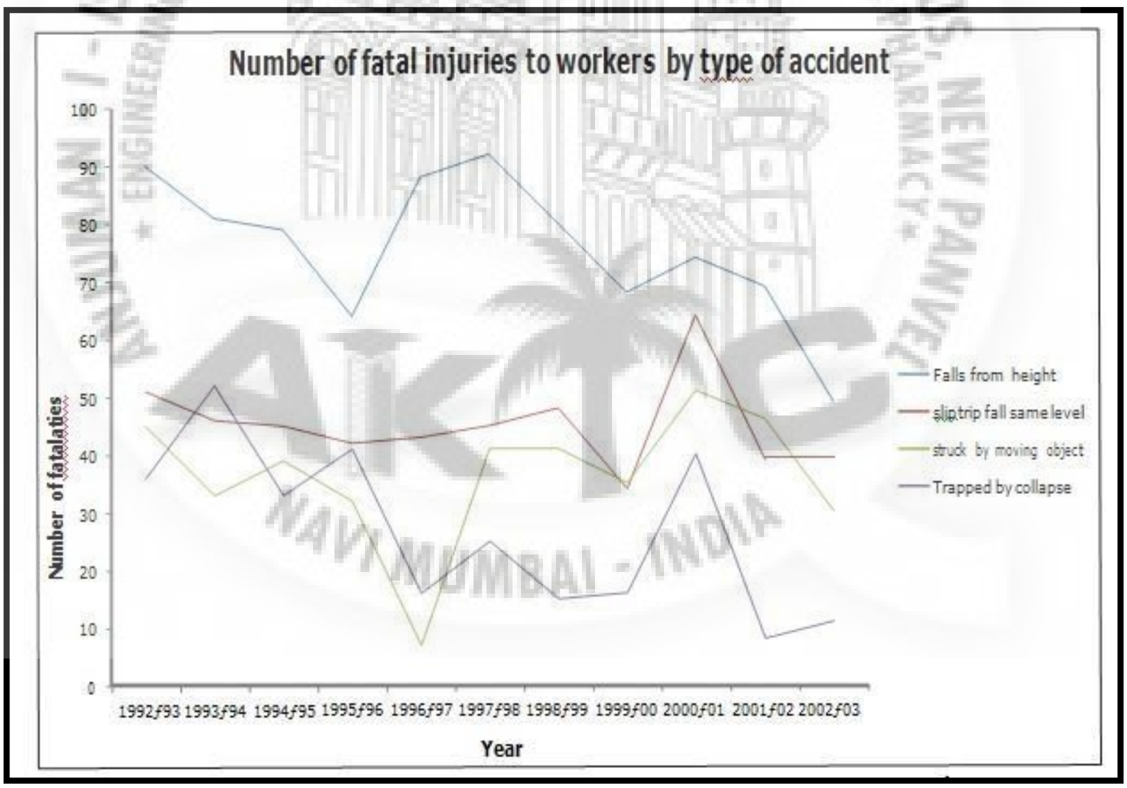


Fig.2.1 Fatal injuries (HSE.1998-2018)

The investigation of the total numbers clarifies the importance of protection at height considering the introduction of the serious injuries and their importance in an even more significant meaning.

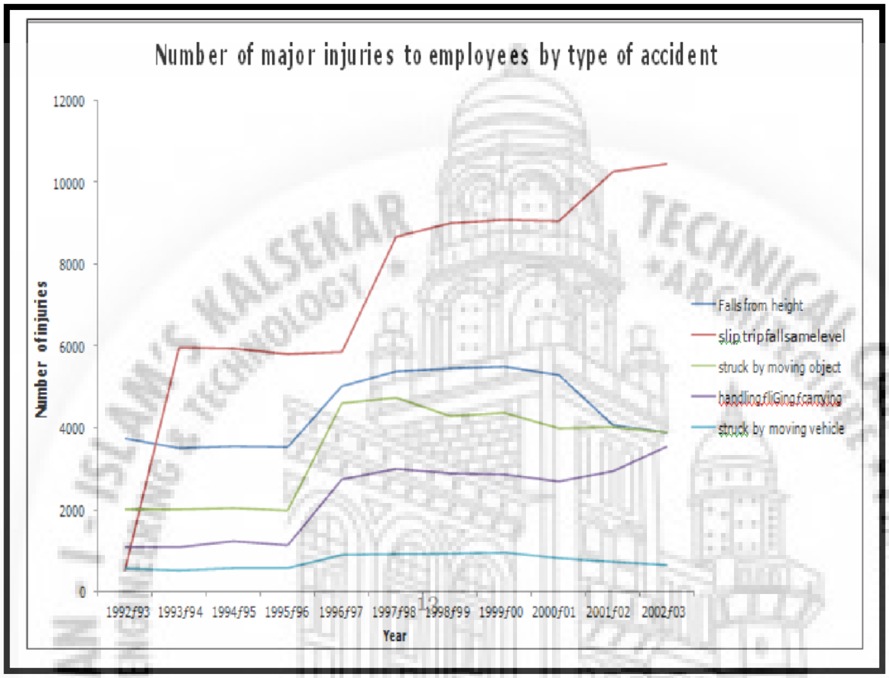


Fig.2.2 Major injuries (HSE.1998-2018)

The trends over the last few decades have tended to be the same according to HSE statistics. Unfortunately, the data does not identify specifically if the fall from a height was due to an evacuation problem or lack of means of escape. However, recent studies into suspension trauma have highlighted the requirement not to leave persons suspended for any period. This has caused a further need to look at using descent control devices as a means of protection in order that the person is lowered to the ground rather than being left suspended. Risk assessment must now take into account rescue and the use of descenders to fill this role. Figure 2.1 and 2.2 shows graphs for the injuries records.

2.2 Descent Control-Current Review

The forerunner of descent control device thinking. In operation today are a number of designs that date back to the original spooled descent design from the 1970's, based on a drum brake. It has two large brake shoes that pivot out and based on gearing allow the person to descend, although not generating sufficient friction to stop the descent unless the user is less than 50 kg. The descent also depends upon the amount of rope that has been deployed on the other side, as on longer descents the weight of rope with associated hardware and body harness on the other side of the unit acts as a counterweight and potential snag hazard. The lifeline used is 8 mm diameter and is a polyester sheath over either a galvanised steel or stainless steel wire, which is inflexible and heavy requiring a reel which must be deployed prior to using the device. In the event of a fire it is not certain if the lifeline without the sheath could operate the brake as the brake depends upon the fibres locating within the drum groove.

2.3 Evacuation & Prior Art Search

Prior to an evacuee being able to escape, using a descent controller, a safe point has to be found or negotiated too, several studies into crowd control, and how best to move people in the event of an incident have been carried out. One such study is known as PEAR (Personal Evacuation And Rescue system) which was developed by three members of the department of computer science, Natl. Chiao Tung University of Taiwan, namely Chu-Yi (Juyi) Lin; Yu- Chee Tseng and Chih-Wei Yi in 2011. In this proposal satellite Navigation is used in conjunction with mobile devices, television, electronic signage and other devices to instruct persons on the best evacuation route through structures or other environments. By using this technology then it has the ability to constantly update the evacuee with the latest information and provide safe route options.

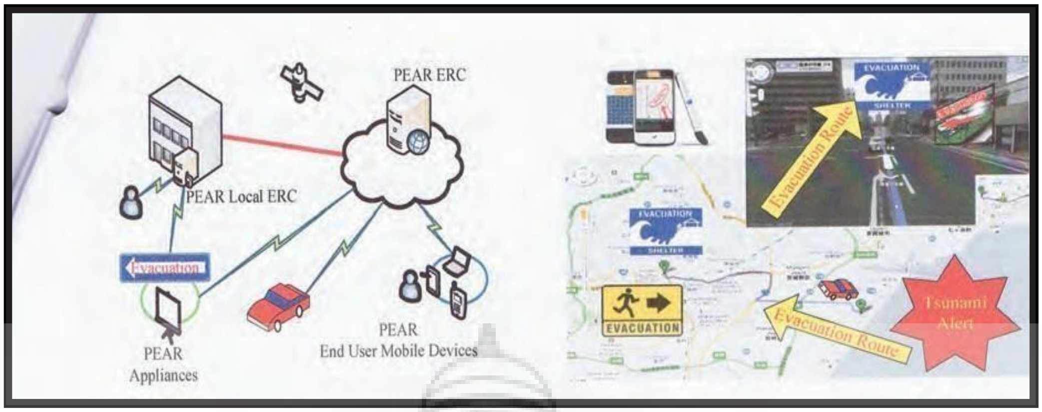


Fig. 2.3 The PEAR system graphic (Natl. Chiao Tung University,Taiwan. 2011)

This type of system has merit when considering land based incidents but may have more problems if implemented on offshore structures such as Oil or gas production platforms. It may also present a way of tracking evacuees and providing instruction directly to them in how to use descent devices, other than that its relevance to this study is limited.

In a paper by Alois Ferscha and Kashif Zia (Lifebelt: Silent Directional Guidance for crowd Evacuation, 2009), they propose the use of a lifebelt for controlling evacuees in a panic situation. The belt would vibrate to commands from the global evacuation control unit, in this way the wearer is directed to the most effective escape route, it was also proposed that the belts would gather data on movement for continual updating and route prediction, this would in theory enable bottlenecks to be avoided. Once more this system is designed to allow the evacuee to navigate to the safest escape point, if at height then that is where the descent controllers would be located. In this section consideration is given to the problem of moving people to a safe area in order for them to evacuate safely. With regard to high rise structures there are two principal ways to move from one level to another, the first is the stair wells which are located through structures and the other being the Elevators. In the event of an incident the elevators are in general off limits as a means of evacuation, often programmed to return to ground if a fire occurs. Elevator shafts are a possible evacuation point for the use of descent control devices as an alternative to running down the outside of the structure.

This relates to a device that controls the elevators and manages their operation in an emergency. The intention is to use the lifts to move evacuees to designated floors for safe exit; this can co-exist with the provision of descenders on these floors for evacuating the building. The device can assimilate information and perform live updates which it can use to move the elevators and people. By channeling people in such a fashion it is hoped that an effective orderly evacuation can be carried out. The device runs alongside emergency broadcasting devices to inform people of the procedures and way out. There is no mention of being able to operate elevators and doors such that the elevator shafts could be used but it would appear that this is a possible extension that could offer alternative options in evacuation if used with descender devices. Figure 2.4 shows the general schematic for the device.

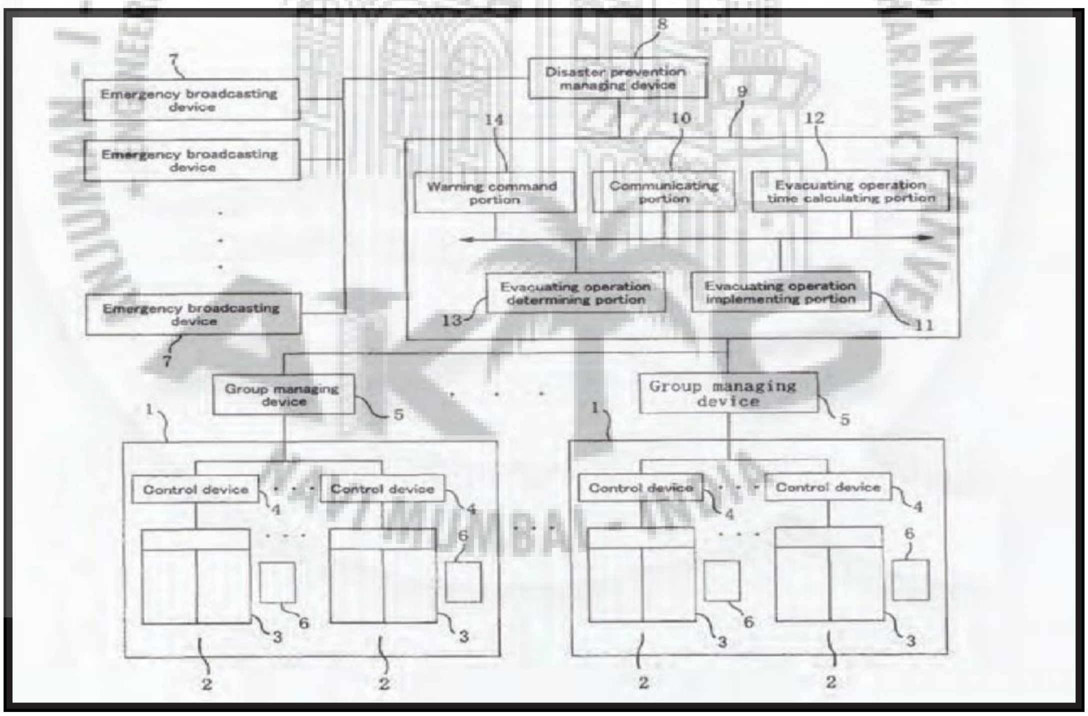


Fig. 2.4 Control schematic Evacuation Assistance Device for Elevator (US

7,963,372 : 2011)

Moving from the concepts of how to move people to a safe point for evacuation, consideration is now given to the actual methods of descending, in 2.1.3.1 the forerunner of modern descenders. In the next part the discussion looks at several devices obtained by the search.

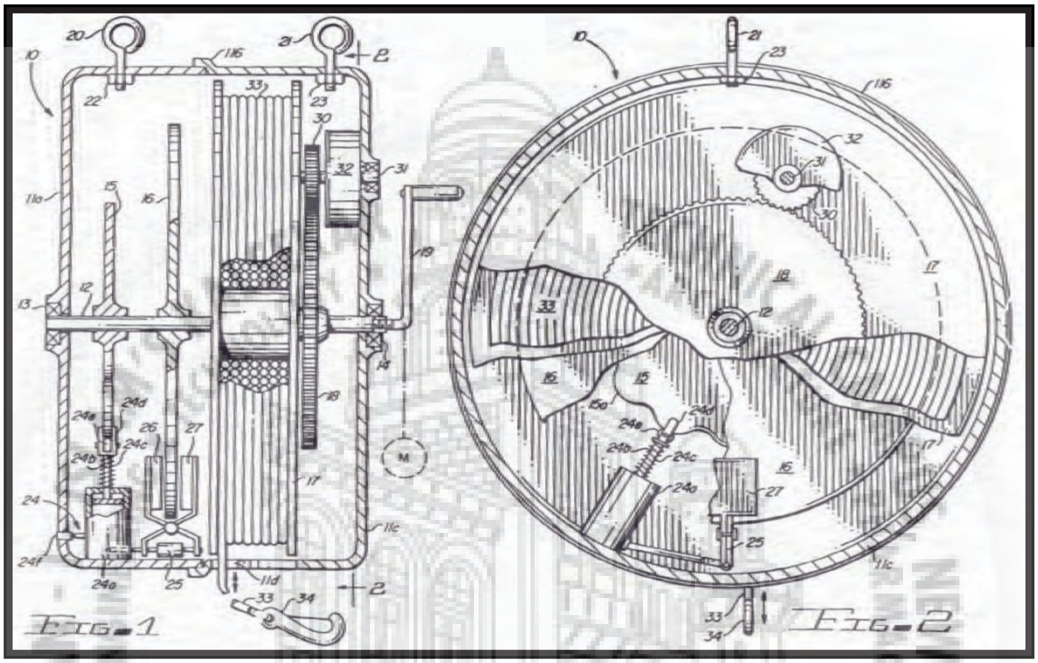


Fig.2.5 Winch for safely lowering a person (US 4,493,396 : 1985)

A number of winch type devices have been modified in order to lower a person from an elevated position to a lower level. one such winch was patented in the USA (US 4,493,396 : 1985) figure 2.5 as shown.

The winch in this case has an over speed brake, in the left hand side to stop the unit if the handle is released. If the brake were set such that the air piston only applied limited pressure to the disc brake then a degree of descent unaided may be possible. This is not the prime aim though, which is for a rescuer to lower the person and the unit using wire as the lifeline would be very heavy in any event. The brake would be hard to control other than for complete over speed stop and the unit is not considered practical for automatic descending. Also based on the winch type of descender is a fire escape apparatus which was filed in the UK by ta-Tan liou and Shiou-Huey Chang (GB 2 238 720 : 1991).

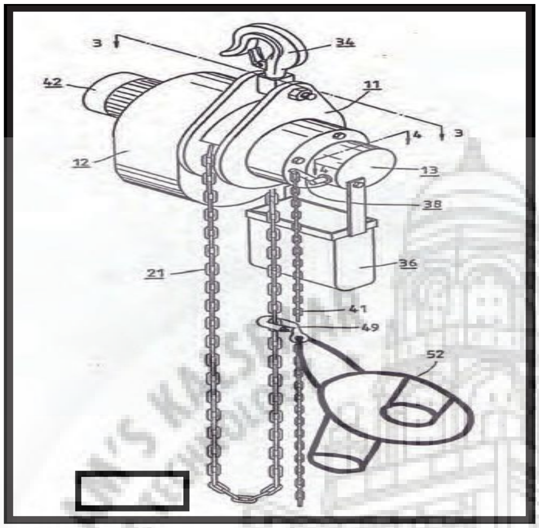


Fig.2.6 Fire escape apparatus (GB 2 238 720 : 1991)

The device is based on the chain hoist, employs a chain, which it is claimed evacuees can clip into the links of the chain, descend either by themselves or multiples. Chain blocks would require a lot of chain which is hard to manage and the feeding is often with problems. It is difficult to determine how the unit would perform in reality, there exists a very complex set of gears with a speed limiting device that is small and appears none compensating. The principal of simply connecting to a link is liked but having studied the arrangements one tends to believe that its use would be an issue if it in fact works at all as a descender. It is an interesting variation on the chain hoist which in the norm operates with ratchets. Figure.8 shows the general arrangement. Portability is a key factor with descender devices, as the unit may need to be relocated in an emergency then compactness and weight are to be monitored. A portable slow descender was patented by takeshi Kikuchi (US 4,986,390 : 1991)as shown in figure 2.6.

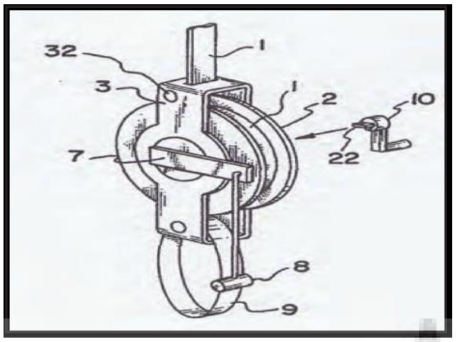


Fig.2.7 Portable slow descender (US 4,986,390 : 1991)

This invention utilises a drum, on which a webbing is wound the descent is controlled by a lever that applies a brake to the inside of the drum. The person is connected to one end of the device via a strop. No indication is given to the method of lifeline termination at either end or the size of brake, from looking at the sectionals it is hard to see how the device would or could regulate for heat. As the device travels with the person, on descent then temperature and rotating parts may be an issue. The principal is similar to the mountaineering, figure of eight and would require levels of training and device know how to operate it safely. The other issue is the brake regulates the descent but in a panic situation, what would have perhaps been better is a dead man’s handle so that you can stop-go stop otherwise you could hang up. The use of tape was however, interesting as most other searches revealed rope or wire as the preferred choice. Roping type device form the main areas uncovered from the search. One such design was patented in the UK by Hans Bloder (GB 2 057 871 : 1980). The device relies upon a rope being threaded through the unit and the action of this producing controlled descent due to friction. The unit can be further regulated manually via cams in the device. In the event of rope being fully used or a problem with the unit then a rope sensor in the device would apply a clamp stopping any further rope movement or descent. Rope camming devices put both twist and loading on the rope which can cause premature wear, also as with other roping devices the rope and way it is mounted are critical to the operation. Again training is an issue as is the ability to have multiple descents quickly and easily, figure 2.8 shows the device.

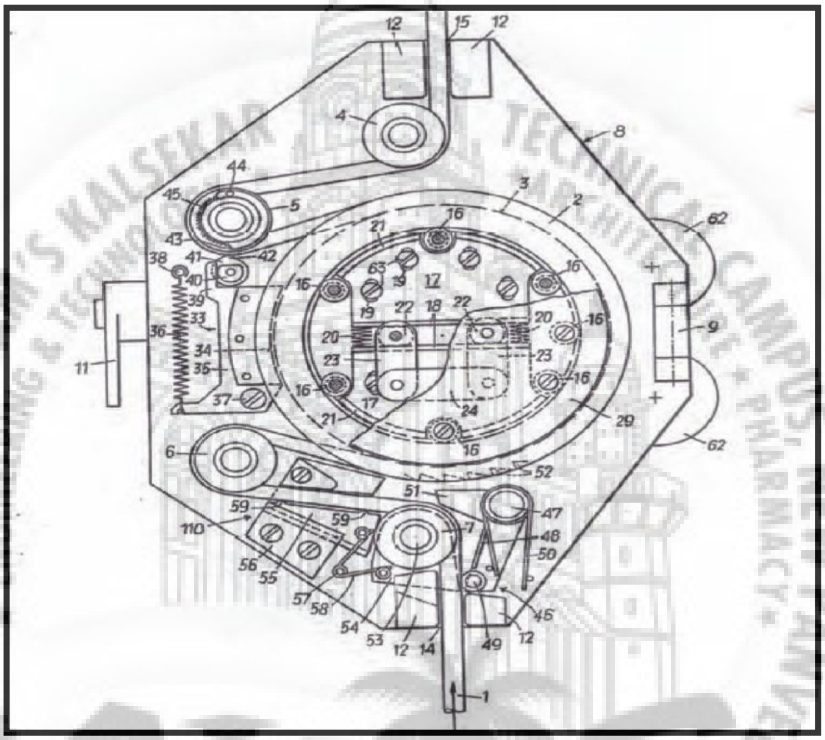


Fig 2.8 Roping down device Hans Bloder (GB 2 238 720 : 1991)

Rope wrapped around or threaded through a device remains the main part of any search carried out. W. E. Forrest patented Personal high rise evacuation apparatus (US 4,550,801 : 1985). Again this invention is reliant upon friction of the rope as it passes through the device. Forrest talks of a simple unit for the none trained within out only in other words the rope is pre loaded and ready to be used once it has been deployed from the bag. Forrest then goes on to cite a second invention which is for the rescue or trained persons. The rescue unit would have the ability for re threading the rope on site and adjustment. At the time Forrest also cites the use of “kevlar’ ropes 5 mm in diameter as an option for his device, this choice would be questionable knowing the poor bend quality of “kevlar”. Speed is determined by how many wraps there is on the drum, suggesting 3 or 4 would cover most cases, reference to speed per wrap as against weight is not given. A common theme with rope devices is the cylindrical approach comprising a central stem or drum upon which the rope is wound. Lewis H. Himmelrich patented a device , namely; Descent with a manually operable brake (US 4,474,262 : 1984) figure 2.9, which has a rope around a centre stem, the rope enters at the bottom and exits at the top. The device has a brake lever which is operated manually by the evacuee, allowing additional control over the descent speed, the lever simply clamps the rope at the bottom. If clamped hard then the descent would stop but as with the previous device reviewed if used in a panic situation, then the descent may stop completely unintentionally with inherent problems of how to get the user to release and lower.

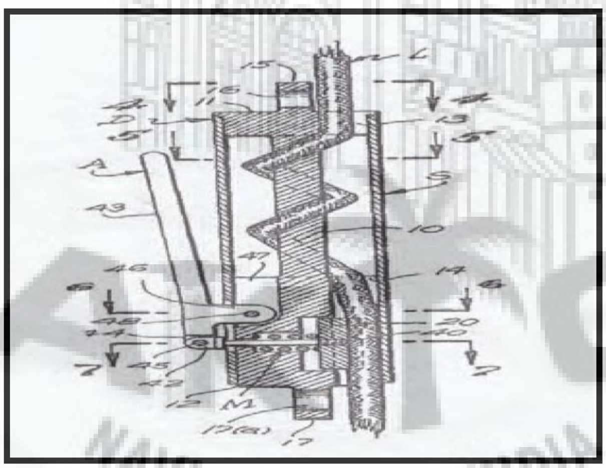


Fig 2.9 Descent with a manually operable brake (US 4,474,262 : 1984)

Further information on types of descenders is given in Appendix 1in particular A1 8.3 to A1 8.5 inclusive. A further variation on the descender with manual override, or more accurately in a stop-go-stop configuration is given by US patent, Descent control device with deadman brake (US 4,883,146 : 1989). The device was invented by Horace M. Varner and Ernest L. Stech and differs from the previous device as the user is required to move an outer cylinder downwards to effect descent, if one lets go then the descent is stopped, if one pulls it to far again the descent is stoppled. this type of device has what is described as a dead man brake.

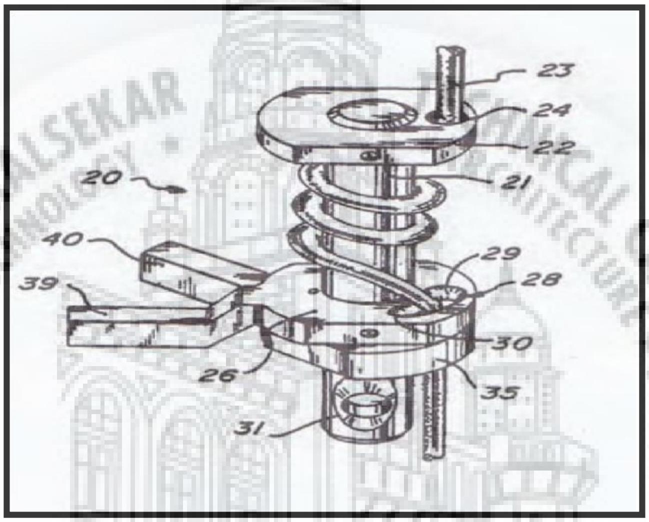


Fig 2.10 Descent Control device with dead man brake (US 4,883,146 : 1989)

Again the rope is wound around the centre stem entering at the bottom and exiting at the top. The number of turns in line with other devices of this type dictates the descent speed and range. One problem with this type of device is the issue of dead man brake, which is designed to make the unit more easy to use, however, if the user were to collapse or encounter any problems then they would be left suspended which in itself is a problem and could require a full scale rescue itself.

A deviation on the wire on the drum theme is contained in US Patent 6,672,428:2004 by Boris Gelman. This device is attached to the back of the evacuee and as they descend the wire is payed out, the drum rotates and the speed control is obtained by moving a hydraulic fluid through a channel. The hydraulic fluid is moved due to an oil damper pumping the fluid this pumping action acts as a retarding force causing the slowing of the evacuee.

Questions arise as to the effect of temperature rise in the unit and the true action of the damper which provides the resistance Also it would be of interest to know the descent speed achieved for various masses and the descent height achievable. With all the wire being paid off from one end of the spindle, this may put a twist into the user as one descends Figure 12 shows the general arrangement of the hydraulic device, from which one can see that the person is connected via a yoke connected to part 42, giving operational concerns due to twist. The hydraulics are also not direct driven as it relies on a pump which may be a further risk as no back up exists.

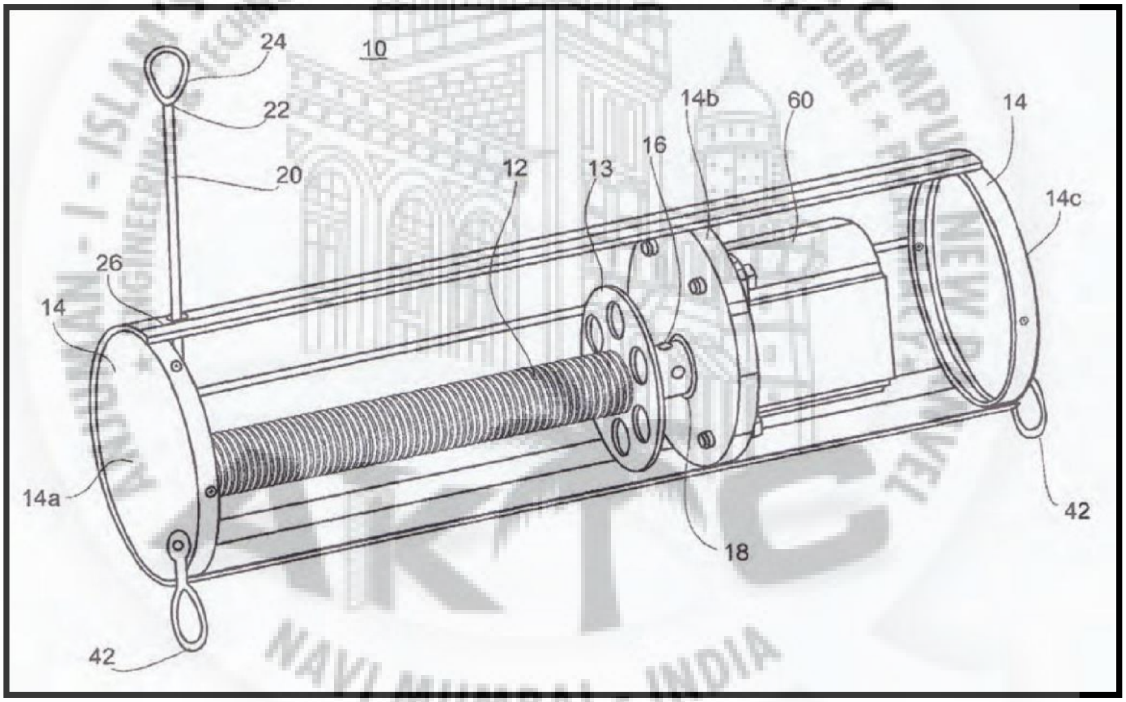


Fig 2.11 Personal descent apparatus (US 6,672,428 : 2004)

Evacuation from height can take other forms, in recent years a variety of slides and constriction tubes have been tested. The slide is well established and familiar to most as used on commercial aircraft for many years. In the USA a patent was filed by Alexandre Targirff and Dean H. Staudt for an inflatable evacuation slide with adjustable decelerator (US 6,298,970 : 2001) figure 2.11 Where this differs from other slides is the inclusion of decelerator ribs which are designed to slow an evacuee down. The more ribs used the slower the descent, It is unclear at what point does the inclusion of additional ribs actually inhibit the descent such that multiple evacuees collide. also the slide would by its own construction have height limitations and comes with stowage and deployment issues. Portability would appear not possible as would the activator required to deploy the slide, if based on liferafts then compressed gas adds weight and bulk further hindering the use in an emergency from none fixed locations. The materials of construction may also be a concern in the event of fire and heat.

This device is an easy to deploy parachute which incorporates sensors which will deploy the parachute after a time period, or can be deployed manually. The unit is light and compact but would suffer from thermals and up draughts if used near tall buildings, also for an untrained user the concern would be, how one steers the chute such that one does not drift into a problem area such as a fire. It is also unclear if the evacuees would have the confidence to strap the chute on and jump.

2.4 International Standards Search

European - EN 341 :1992 (BSI.1992)

The EN standard's main aspect is the energy rating or classification for the descent device. It splits into four categories A, B, C and D where A is the highest rating for continuous use and D is for single use only. It also relates the classification to the static strength requiring far higher for Category A (12 kN) then for category D it is far lower (5 kN). The aim is to try, as far as is reasonably possible, to have a distinction between one- off personal devices and multiple use devices. The standard forms the base for all other standards and is considered to be the standard that should be first applied to all research. The problem is that the standard contains limits and test protocols that are in practice very difficult to achieve as even notified bodies in the various European Community Countries have no way of testing the units. In order to carry out this research, several purpose designed test rigs have had to be constructed in order to verify the design concepts. The descent velocity aim is 2.0 m/s and this has to be achieved over a weight range from 30 kg to 150 kg. Energy tests are carried out with a 75 kg weight, based on a 100 m drop and the test would have to be repeated 7 times to achieve 0.5 E6 J Class C rating, whereas the test would be run over 20 m using a 100 kg mass to achieve 0.02 E6 J class D rating. The energy rating requirement highlights the substantial difference in testing the devices to achieve each class. In addition Class A - C require a static strength of 12 kN where as the Class D device only requires a static strength of 5 Kn.

Canadian - CSA Z259.3-99 (CSA.1999)

As with the European standard, the Canadian standard is based on energy but class D in the European has no equivalent in this standard. As would be expected the additional tests relate to low temperature due to the Canadian environment with tests carried out after conditioning to - 30 0 C (table 2.1).

American - ANSI Z359.4-2007 - (ANSI.2007)

In this instance the standard has only two categories single use and multi use. Upon reviewing the standard it is based on a combination of the other standards which, as with the Canadian standard, has a test protocol that is based on heavier weights (300 lbs or 136 kg) than the European standard (100 kg).The ANSI standard is the latest attempt by International bodies to try to regulate what descent equipment is being used and is a reflection of the growing need for evacuation devices. The American engineers following on from the Twin Tower attack in 2001, are looking more and more at evacuation and rescue, (table.1) There is a dearth of information relating to descent control devices in the public domain which could be drawn upon, much of the information that was found unfortunately had little relevance to the main aims of this research. High profile disasters are recorded, as are the various groups set up to try to improve the situation for the future. However, the specific information is either restricted as commercial, in confidence or simply does not exist. From discussions with several bodies and notified bodies (authorized persons man dated under European legislation to test safety products to ratified standards) world- wide it is clear that little research has been done and there is a lack of data or test facilities.

Table 2.1 International standards relating to descent control

	EN 341: 1992	**ANSI Z359.4-2007**	**CSA Z259.3-99**
Class / Type:	A, B, C & D	Single Use & Multi Use	1E, 2E, 2W & 3W
Material Requirement:			
- Strength of Wire rope	1770 N/mm^2	3000 lbs (13.3 kN)	13.4 kN
- Strength of Strap		3000 lbs (13.3 kN)	13.4 kN
- Case Displacement of	<15 mm over 2 m strap length (test accord-		
- Elongation of Strap	<8% (test according to 5.2 of EN341:1992)		
Descend Line Termination	12 kN forClass C		4kN for 3 minutes at the tail end of descend
	5kN for Class D		
Holding Load of Hand Oper-	Max 120 N to hold 80 kg test weight		
Static Strength	Maintains 12 kN (5 kN for Class D) for 3	Maintains 2700 lbs (12 kN) for 1 minute	Maintains 12 kN for 10 minutes
	Maintain 5kN for 3 Minutes Perform test be-		
Descent Energy Tests	Class C: (0.5E6 J) 75kg test weight, 100 m	Multi Use: (300,000 ft-lbf) 310 lbs test	136kg test weight, Descend height = device

	Class C: (0.5E6 J) 75kg test weight, 15 m	Multi Use: (300,000 ft-lbf) 310 lbs test	136kg test weight, Descend height = device
	Class D: (0.02E6 J) 100kg test weight, 20	Single Use: (30,000 ft-lbf) 310 lbs test	136kg test weight, Descend height = device
			Extra tests for wet, cold & wet/cold conditions
Functional Test (with condi-	After Energy Test, this test shall be carried	After Energy Test, this test shall be carried	
	Class C: 30 kg & 150 kg test weight, De-	130 lbs & 310 lbs test weight, Descend	
	Class C: 30 kg & 150 kg test weight, De-	130 lbs & 310 lbs test weight, Descend	
	Class D: 30 kg & 100 kg test weight, De-	130 lbs & 310 lbs test weight, Descend	
	Meet Descend Velocity below	Meet Descend Velocity below	
	Extra test for wet condition required for	Extra test for wet condition required	
Descent Velocity	Class C: 0.5 m/s - 2.0 m/s.	1.6 fps - 6.6 fps (0.5 m/s - 2.0 m/s)	Type 1E: <2.0 m/s over solid ground, <4.0 m/s
	Class D = to or less than 2 m/s		
Temperature Rise of De-	<48°C any parts touched during energy test		<65°C any parts touched during energy test
Manual Descender (Hand	<2.0 m/s after control device of hand oper-	<2.0 m/s after control device of hand oper-	
Special requirement for	Shall be designed in a way that it cannot be		
Dynamic Strength		220 lbs (100 kg) test weight, 2 ft (0.6 m)	220 lbs (100 kg) test weight, 2 ft (0.6 m) free
Salt Spray			No evidence of corrosion per ASTM B117
Resistance to Slippage			Type 2E & 2W only

			Hands-Free Lockoff: 3 kN applied to device
			Panic Lockoff: 3 kN applied to device (with 45
Residual Static Strength			The descend line shall retain a min 90% of its

A review of proposed changes to the European standard has also been considered as a PREN (pre ratified standard) publication, the main points remain. However the way designs are to be classified between evacuation and rescue is the main change as designs now stated for rescue under proposed changes would not require EN testing. The move is to encourage new designs that do not or cannot fit within the original EN 341 scope, but can perform rescue tasks. The testing regime for descenders remains but in all discussions and from all searches the ability to test to the standards remains a problem.

The principal behind egress methods is to provide a means of emergency escape for any person whilst working or residing at height. In the event of an incident then conventional methods of escape may not be possible. Lifts would become static, ladders and walk ways potentially unsafe with fire escapes involving numerous landings and levels impracticable or impassable. If one then adds the effects of smoke, heat, fire, gases, structural collapse or chemicals then entrapment is a real possibility. Disabled or injured persons would also present a challenge, the challenge being to get them down safely. When one looks at modern structures, industrial or private and read the contingency information provided there is a real lack of escape provision in the event of fire or structural collapse. The twin tower disaster had both these factors demonstrated in the harshest fashion and with Piper Alpha you had fire as the principal issue. What was present in both cases was the lack of provision for escape from height where the traditional exits were blocked or the height and time were prohibitive. In America one has OSHA regulations, which touch upon the subject. OSHA 1910.35 allows for the consideration of windows or other wall exits as a potential area for evacuation using descent devices. When considering wall exits, irrespective of type chosen the first consideration has to be where one connects a descent device (the anchorage) and how one connects it. Even before an exit is chosen the anchorage has to be present and clearly identified. It is possible that the equipment would provide an indication of temporary anchorages that would work. It may be impracticable to spend time searching for a marked and approved anchorage. The collapse of the twin towers demonstrated the relative short time frame that one may be presented with, in any event the rule is clear and that is a person must be getting away from the problem as quickly as possible. There has to be a compromise between many factors but EN341-1993 states that the descent speed is limited to 2 m/s and strength is 12 kN. If these are to be applied to high level evacuation then they may prevent a useable solution due to size and time constraints. The 12kN level was introduced to equal the fall arrest standards such as EN360-2002 where lifelines have to manage shock loads. However in the case of descent controllers the argument is that they will pay out and most are continuous so the shock loadings developed are minimal. In most if not all cases tests have shown that the peak forces seldom go above 10% above a person's weight. This would give a level of 2 kN as a requirement for line strength and would allow smaller gauges. In parachute terms a parachutist who employs a body roll landing would be capable of 6.4 m/s and if one was evacuating to water then 4 m/s may be more practicable, even on land 4 m/s may be a more useable speed of descent. In developing a device variable rates may be applied or even zoned evacuation, for example one may supply devices to floor levels which operate a different speeds and may slow as descent distances reduce.

A recommendation by Harold Steinberg in his 1977"Study of Fall Safety equipment" concluded that 15 ft/sec or less for uninjured persons and 10 ft/sec for injured persons be adopted. In the event as demonstrated by EN341-1993, 2 m/s or 7 ft/s was adopted.

The design approach for a personal evacuation device-Introduction to principles

Research into the area of descent control as used for evacuation and rescue can be an effective way to avoid injury. Improvements in descender design in particular for use by untrained personnel has been very limited to date. Some examples are cross over designs from mountaineering, such as figure of eight descenders and belay devices, figure 3.1 shows such a device with origins in mountaineering, although serving a need are not considered adequate for mass evacuation or the unskilled user. The approach including some passive improvements has been held back due to other considerations such as cost and the lack of test facilities to try out and develop designs. The descent control unit requires either movement or manual control in order to operate. Due to the nature of where they would be used, the use of an external power source is not very practical or desirable. The fact that the environment can change considerably even during use is a factor that influences design. The design has to be made in such a way that even if not functioning perfectly, it would still be able to allow a user to descend safely. If the units and their operation have no back up, so the risk of injury or worse would always be prevalent and the designer has to be aware of this shortcoming. The proposed research designs described in this thesis are based on reliable activation and use mainly gravity and centrifugal forces to effect the descent. The designs are able to be reused without resetting, which eliminates the use of manual operated devices as in the event of trauma the device has to still function Evacuation. The main use for any descent device is evacuation either as a result of an accident, suspension or escape. The current research looked at simple manual devices semiautomatic devices and fully automatic devices for use over land and water.When designed correctly, the protection of the person during evacuation is paramount and the more data that can be drawn upon to help facilitate this outcome the safer it is for not only the user, but also for rescue teams and other individuals who may become caught in the evacuation process. Lessons learned from the disasters such as Piper Alpha (Lord Cullen inquiry 1990) can be drawn upon in design for descending into the water, too fast and the risk of secondary issues such as premature deployment of the life preserver, too slow and the evacuee is put at risk of suspension in a potential danger zone such as flash fire or explosion. The proposed research concept described here is based on automatic response together with simplified mechanical mechanisms that are quite tolerant to external changes and different weights. Furthermore, the study looks at materials and construction to minimize weight and improve portability, which when included in the design outline, improve the device.

2.5 The Design Approach For A Personal Evacuation Device

Research into the area of descent control as used for evacuation and rescue can be an effective way to avoid injury. Improvements in descender design in particular for use by untrained personnel has been very limited to date. Some examples are cross over designs from mountaineering, such as figure of eight descenders and belay devices, a device with origins in mountaineering, although serving a need are not considered adequate for mass evacuation or the unskilled user. The approach including some passive improvements has been held back due to other considerations such as cost and the lack of test facilities to try out and develop designs. The descent control unit requires either movement or manual control in order to operate. Due to the nature of where they would be used, the use of an external power source is not very practical or desirable. The fact that the environment can change considerably even during use is a factor that influences design. The design has to be made in such a way that even if not functioning perfectly, it would still be able to allow a user to descend safely. If the units and their operation have no back up, so the risk of injury or worse would always be prevalent and the designer has to be aware of this shortcoming. The proposed research designs described in this thesis are based on reliable activation and use mainly gravity and centrifugal forces to affect the descent. The designs are able to be reused without resetting, which eliminates the use of manual operated devices as in the event of trauma the device has to still function.

2.6 Evacuation

The main use for any descent device is evacuation either as a result of an accident, suspension or escape. The current research looked at simple manual devices, semiautomatic devices and fully automatic devices for use over land and water. When designed correctly, the protection of the person during evacuation is paramount and the more data that can be drawn upon to help facilitate this outcome the safer it is for not only the user, but also for rescue teams and other individuals who may become caught in the evacuation process. Lessons learned from the disasters such as Piper Alpha (Lord Cullen inquiry - 1990) can be drawn upon in design for descending into the water, too fast and the risk of secondary issues such as premature deployment of the life preserver, too slow and the evacuee is put at risk of suspension in a potential danger zone such as flash fire or explosion. The proposed research concept described here is based on automatic response together with simplified mechanical mechanisms that are quite tolerant to external changes and different weights. Furthermore, the study looks at materials and construction to minimize weight and improve portability, which when included in the design outline, improve the device ability to meet or overcome potential hazards. The action of the design should be to fool-proof and suitable for adults, children and the disabled. To support the investigation of a comprehensive design for the evacuation device several test rigs were developed and a number of designs were manufactured for\ analysis and full function testing with a specially commissioned articulating manikin, Torso (EN-1992 (figure 13) and ANSI/CSA-2007 (figure 14)), and weights to fully understand visual performance.

Fig 2.12 CE Torso - 100 kg torso acquired for testing

Fig 2.13 ANSI/CSA Torso 100 to 160 kg torso acquired for testing

Ability to meet or overcome potential hazards. The action of the design should be to fool-proof and suitable for adults, children and the disabled. To support the investigation of a comprehensive design for the evacuation device several test rigs were developed and a number of designs were manufactured for analysis and full function testing with a specially commissioned articulating manikin.

2.7 Rescue

The second criteria for a descent device are rescue and the ability to move and deploy a unit to assist a casualty or an individual who is in a precarious or dangerous position. The proposed research concepts examined here take into account this requirement and the data and information gained by this research is to assist fellow engineers and designers in finding solutions to potential problems, special rescue dummies were manufactured for trials with the designs as shown in figure 15, Figure 16 shows Rescue sling – body device and Figure17 shows Rescue triangle body device for evacuation and rescue. The introduction of descent controllers in rescue and evacuation would enable the protection of/and preservation of lives. The interaction between the design and the individuals is such that in a moment of severe stress the design is easy to operate by even the lowest skilled individuals. This study will put forward designs and evaluate those providing data. Furthermore, during the course of this study several body devices were developed and tested with the descender designs using test rescue dummies that were constructed specifically for this research.

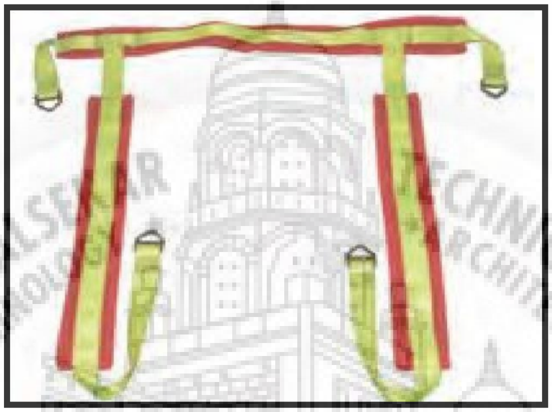


Fig 2.14 Rescue sling – body device

Fig 2.15 Rescue dummies -30 kg and 100kg special manufactured dummies to during testing

Fig 2.16 Rescue triangle body device for evacuation and rescue

Interdependence between the individual and descent design

There is interdependence between the individual who is using the device and the device itself. If misused, even the simplest designs would have the potential to fail. The author has developed designs based on the minimum requirement for training in addition to covering the broadest range of applications. Furthermore, environmental influences such as fire, explosion, height, weight, disability, collapse of structures, ground condition or type, and weather all add to and define the descent design that can be adopted. The final part of the descent process is the body device two designs and any design is dependent upon its ease of use and the design of the body device or harness, which has to be able to fit and meet the individuals needs for height, weight, ease of donning and importantly confidence in order for the person to use the device and for the descent design to perform correctly.

2.8 Vertical descent

Escapes from Oil/Gas production platforms, overhead cranes, hotels, office blocks, chimney stacks, and elevated workstations are examples of typical applications for vertical descent. Vertical systems are generally designed to allow the descent of one or two persons at any one time per system. The design of some devices is that once the first person is down then a second may descend, like a see saw arrangement, figure 18.

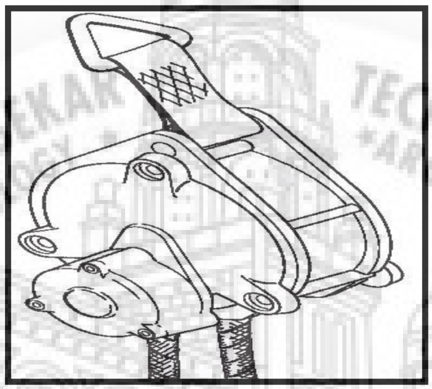


Fig 2.17 Seesaw type of device

Descent controllers fall into two categories irrespective of the method employed. They are either automatic or manual. An automatic descent device is one which is pre-set with a descent speed and cannot be adjusted or over ridden in use. A manual device is one which requires user control at all times as shown in figure 18. Automatic devices operate at 2.0 m/s +/- 10% in line with standards and the longest device found on the market has a distance of 35 m. Weight of life line or rewind unit size being major limiting factors. Manual descenders have to operate within the same speed constraints but it may be possible to increase descent distances to greater than 60 m. For practicable reasons they would normally be less than 100 m. If a pulley type systems is used then 20 m would be more normal as they work on either a 4 or 3:1 ratio which would require substantial amounts of rope and also run the risk of ropes being tangled.

2.9 Angled Descent

If a structure is collapsing or if a fire is possible at the base of the structure then angled escape is considered. The method normally employs a guideline in order that the user can escape. As a rule the speed of descent would be greater but the removal of a user from the danger zone is considered essential, so this lends itself to a variable descent speed which is considered in the main body of the research.

2.10 Friction

These devices can be manual or automatic or a cross between the two. They represent around 99% of all devices on the market and run on webbing, rope or wire. The first common feature between all devices is that they require the user to wear an attachment point in the form of a full body harness or helicopter strop. For young children or injured/disabled persons the harness/strop can be substituted by a sling or seat device. The second common feature is that they all have the same operating parameter that is a descent speed of 2.0 m/s and weight limits of 30 to 150 kg. In reality most devices are designed to take two persons descending together in order to allow for rescue so a more usual upper limit of 200 kg is applied for this design. The research aim is 150 kg. The higher level of 200 kg has been chosen to permit or allow for a rescue person and their equipment. The third common feature that has to apply is the device must be compact, easy to use and light and transportable. Figure 19 shows a sketch of a traditional body device as used by helicopter rescue services for winching people onto their craft.

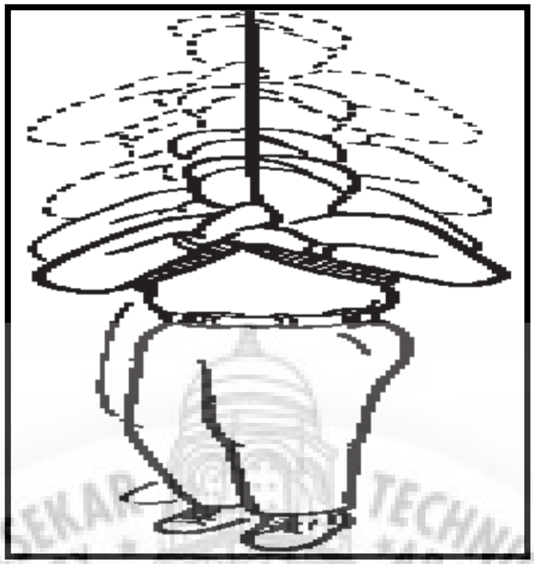


Fig 2.18 Helicopter strop

2.11 Inertia Reel

This type of device has a lifeline on a drum or spool. Lifelines can be made from wire, webbing or fiber (rope). As the user moves away from the device the lifeline pays out. To descend there are two main methods, the first has a braking mechanism that is permanently engaged and the other relies on a trigger such as centrifugal force caused by a fall which engages a brake. The device drum has a spring that rewinds the lifeline when the user moves towards the device or disconnects from it. This type of device is restricted by the size of the rewind springs to less than 60 m and the rewind mechanism can have inherent safety issues at it rewinds the lifeline. This type of device is fully automatic as the speed is pre-set at the point of manufacture and there is no provision to override the device once it is in action. If one is descending on this type of unit and a hazard occurs below, you such as a fire then there is nothing the user can do to overt the danger.

Fig 2.19 Inertia reel prototype descender

2.12 Lock Off Horns

Used in climbing for many years as an abseil device it relies on a rope passing around a forged frame, normally aluminium or titanium. The traditional shape is that of a shown in figure 21, there have been a number of iterations adding horns etc., but the principal is the same in each case. These devices are manual and rely on training for safe use they also put a twist into the fiber rope that reduces the rope life. Normal rope size is 11mm diameter, which does affect the practical use, as the rope becomes very heavy and hard to manage.

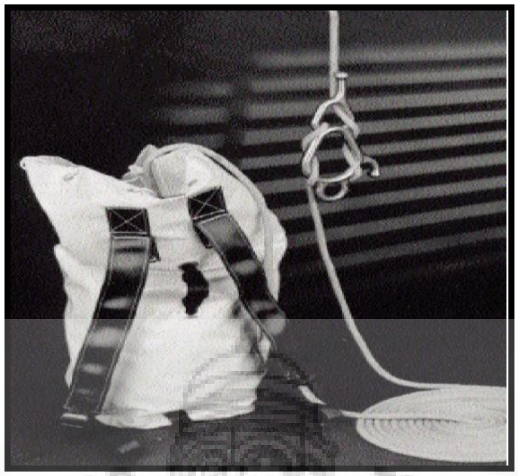


Fig 2.20 Example with lock off horns. Sample was made from titanium known as a

"Fisk" Descender

2.13 Spiral

This type of device is a development on from the figure of 8 abseil unit in that instead of twisting the rope around the 8 frame it is passed around a centre stem, the more turns the slower the descent. Unlike its forerunner this type of device can be produced with a manual override mechanism. The override versions have the centre spindle and the outer tube. However the outer tube is sprung loaded so that if one applies too much down force one traps the rope and stops, if one lets go then the spring pushes the tube upwards and traps the rope so one stops. These devices still require training but the amount of training is reduced and the devices fitted with override make them fool proof in operation. Once more they do use large ropes and the effect of twist coupled with friction reduces rope life. A smaller version using 9mm rope was developed but limited to 25 m. As shown in figure 22 and figure 23.

Fig 2.21 Spiral device with cylinder (completely manual)

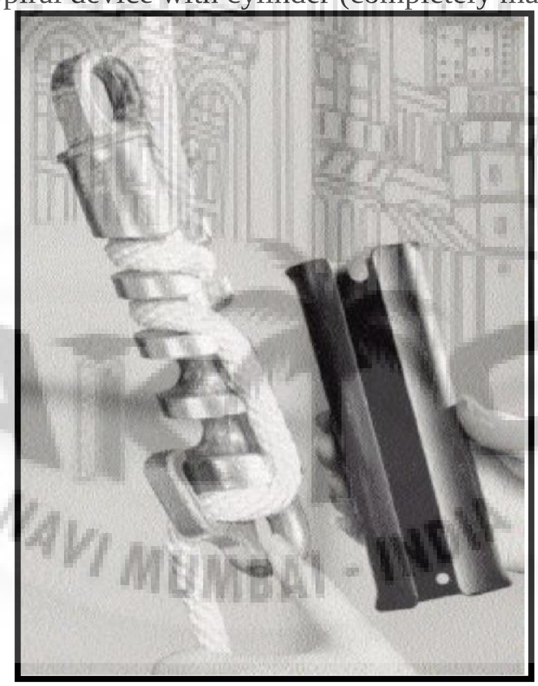


Fig 2.22 Exploded shot showing the centre spindle, it shows two wraps but this can be increased to 3 wraps for slower descents

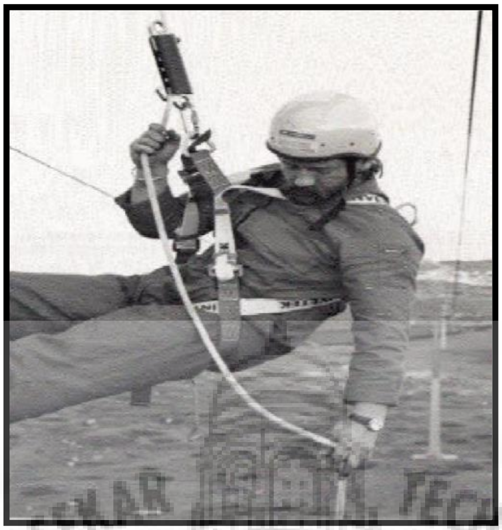


Fig 2.23 Spiral device, easier to use & relies on the user for control, training would be required.

2.14 Cam

In order to address the issues of rope wear and the need for more user control, descent devices are altered to try to stop the excessive spindle wear associated with spiral devices. The change involved threading the lifeline through a simple device and applying control using a hand lever through the use of cams. Depending on the threading the user can increase or reduce friction to limit the maximum descent speed.

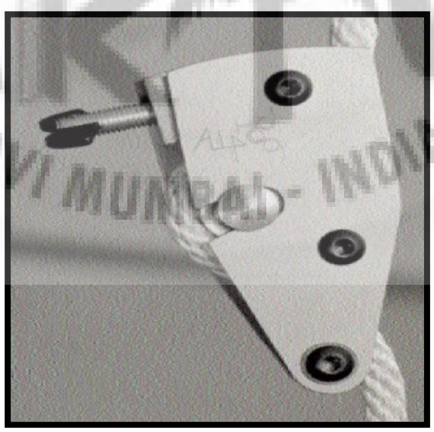


Fig 2.24 Speed adjusting screw (top of the device)

Chapter- III

3. THEORETICAL BACKGROUND OF MECHANISM

A centrifugal brake mechanism for a controlled descent device, and a drum device employing it, are described. The brake mechanism comprises a circular wheel configured and operable to rotate about an axis of rotation thereof, an axle extending along and rotatable about the axis inside a central cavity of the wheel and having two or more parallel shaft rods extending inside the cavity substantially perpendicular to the axis of rotation, a gear system for transferring rotations of the wheel into counter- rotations of the axle, one or more brake elements each having two or more pass-through bores for slidably mounting over the two or more parallel shaft rods, two or more springs mounted over the parallel shaft rods between the brake element and the axle, and a friction enhancement mechanism for increasing friction forces between the brake elements and the inner wall the wheel responsive to increase in angular velocity of the wheel.

There is a need in the art for compact and efficient centrifugal brake mechanisms for a controlled descent device configured to be attached to a harness wearable by a descending user and capable of rapidly damping angular velocity of a rotating body *(e.g.* , a wheel, drum, or cable reel) of the device. Embodiments of the centrifugal brake mechanism of the present invention are particularly beneficial for drum devices of controlled descent devices configured to regulate the speed release of a cable spooled in the drum device, and guarantee continuous cable release from the device until reaching safe ground, and prevent suspension trauma. For this purpose a friction enhancement mechanism is used in some embodiments for increasing friction forces in response to increase in angular velocity of the cable drum. The centrifugal brake mechanism of the present invention is configured to allow substantial reduction of the geometrical dimensions of the drum device by compactly arranging its components inside a circular central cavity formed inside a cable reel/drum, of the drum device, on which the cable is spooled. Brake elements *(e.g.* , brake shoe arrangements) mounted inside the central cavity are slidably coupled to a rotatable axle/shaft coaxially mounted inside the cable reel, and a planetary gear system is used to transfer rotations of the cable reel into counter-rotations of the axle. This configuration causes the brake elements to rotate inside the central cavity in a direction opposite to the direction of the rotation of the cable reel, and responsively to radially slide outwardly towards an inner wall of the cable drum due to centrifugal forces applied over them, and exert friction forces which slow down the angular speed of the cable drum. In some embodiments the brake elements are mounted inside the cavity for radial movement over two or more parallel shaft rods attached to the axle. As the brake elements slide over the shaft rods distally away from the axle their front faces become pressed against the inner wall of the cavity and apply friction forces there over, thereby damping the angular velocity of the cable drum and consequently slowing down the descent speed. In some embodiments the brake mechanism comprises a friction enhancement mechanism configured to damp the angular speed of the drum by increasing the contact surface area of the braking elements used to apply the friction forces. The friction enhancement mechanism is preferably configured to provide engagement between one or more circular rails and corresponding one or more curved grooves engage able with said one or more circular rails, provided on the brake elements and on the inner wall of the cable drum. In this way, the friction forces evolving between the brake elements and the inner wall of the wheel are progressively increased responsive to increase in angular velocity of the wheel. Particularly, in addition to the friction obtained between the front faces of the brake elements and the inner wall of the cable drum, as the angular speed of the cable drum is increased, the circular rails progressively become engaged in the curved grooves, which add to the friction forces a progressively increasing friction component. The one or more curved grooves may be provided on the front faces of the brake elements and/or on the inner wall of the cable drum, and one or more corresponding circular rails may be provided on the inner wall of the cable drum and/or on the front faces of the brake elements. For example, in some embodiments the front faces of the brake elements comprise one or more curved grooves and the inner wall of the cable drum comprises one or more circular rails radially protruding inwardly from the inner wall of the cavity, each circular rail configured to become engaged inside curved grooves of the brake elements, while the respective brake elements contact the inner wall. In one aspect there is provided a centrifugal brake mechanism for a controlled descent device and being configured to be attached to a harness wearable by a descending user. The centrifugal brake mechanism comprises a support structure configured for attachment to the harness, a circular wheel having a circular central cavity and being attached to the support structure to allow it to be rotated about an axis of rotation of the wheel, an axle mounted inside the central cavity and configured and operable to rotate about the axis of the wheel there inside and comprising two or more parallel shaft rods attached thereto and extending substantially perpendicular to the axis of rotation, a gear system configured and operable to transfer rotations of the wheel into counter-rotations of the axle, one or more brake elements each having two or more pass- through bores for slidably mounting inside the central cavity over the two or more parallel shaft rods and configured to radially slide towards an inner wall of the wheel encircling the cavity in response to the counter-rotations of the axle and contact and apply friction forces over the inner wall by a front face thereof. The centrifugal brake mechanism further comprises two or more springs mounted over at least one of the shaft rods between the brake element and the axle. A friction enhancement mechanism is used in some embodiments for increasing friction forces responsive to increase in angular velocity of the wheel. The friction enhancement mechanism is configured for providing additional engagement between the circular wheel and the brake elements by one or more circular rails and corresponding one or more curved grooves engageable with said one or more rails. The friction enhancement mechanism is configured to progressively increase friction between the brake elements and the inner wall of the wheel responsive to increase in angular velocity of the wheel. In some possible embodiments the friction enhancement mechanism is implemented by one or more curved grooves provided in the each brake element and one or more circular rails provided in the inner wall encircling the cavity. The circular rails are configured to be received inside one of the curved grooves when the brake elements contact the inner wall, to thereby increase the applied friction forces. The one or more curved grooves form in some embodiments shoulder structures in the outer faces of the brake elements, and each of the one or more circular rails can be formed by two circular grooves formed in the inner wall. In this way, each circular groove is configured to receive one of the shoulder structures of the brake elements when the brake elements contact the inner wall, to thereby increase the applied friction forces. Geometrical shapes of at least one of the curved grooves and of a respective one of the circular rails configured to be received in it, may be adapted to progressively increase the contact surface area of the respective brake element according to the speed of rotation of the wheel, to thereby increase the friction forces responsive to increase in angular velocity of the wheel. Additionally or alternatively, one of the one or more curved grooves may comprise a tapering groove section in which opposing sides of the groove taper towards the axis of rotation, and at least one of the one or more circular rails may comprise a corresponding tapering rail section configured to be received inside the tapering groove section. Optionally, and in some embodiments preferably, the gear system is a planetary gear comprising a sun-gear fixedly attached to the axle, one or more planet gears attached to said support member and meshing with the sun-gear, and a ring-gear formed over a portion of the inner wall of the cavity and meshing with said one or more planet gears. In some embodiments, the gear system is configured to rotate the axle during rotation of the wheel in an angular velocity whose magnitude is greater than the magnitude of the angular velocity the wheel. For example, and without being limiting, a speed ratio of the gear system may be about 1 to 5.3. In another aspect there is provided a drum device for controlled release of a cable spooled therein and anchored to an external support by a free end thereof, and being configured to be harnessed to a descending user for guaranteeing continuous descent of the user while preventing suspension trauma. The drum device comprising a housing having a cable release opening for passage of released cable portions therethrough, and the centrifugal brake mechanism as described hereinabove or hereinbelow. For example, the drum device comprises a cable reel on which the cable is spooled, and the cable reel is mounted inside the housing for rotation about an axis thereof during the release of the cable through the opening, an axle mounted inside a central cavity of the cable reel and configured to rotate thereinside about the axis of the wheel, a gear system configured and operable to transfer rotations of said cable reel into counter-rotations of said axle, and one or more brake elements slidably coupled to the axle inside the central cavity and configured and operable to radially slide towards an inner wall of the cable reel encircling the cavity in response to the counter-rotations of the axle, and to contact and apply friction forces over the inner wall. The brake elements and inner wall of the wheel are adapted in some embodiments to implement a friction enhancement mechanism implemented by one or more curved grooves and corresponding one or more circular rails, as described hereinabove and here in below. Similarly, geometrical shapes of at least one of the curved grooves and of a respective one of the circular rails may be adapted to progressively increase the contact surface area of the respective brake element according to the speed of rotation of the wheel, to increase the friction forces responsive to increase in angular velocity of the wheel. At least one of the one or more curved grooves may comprise a tapering groove section, and at least one of the one or more circular rails may comprise a corresponding tapering rail section, as described hereinabove and herein below. The drum device may comprise one or more shaft rods attached to the axle substantially perpendicular to the axis of rotation, and each brake element may comprise one or more pass-through bores for slidably mounting it over the shaft rods for it to radial slide there over. One or more return springs, each spring being mounted over one of said one or more shaft rods may be used to mechanically couple between the axle and the brake element mounted over the shaft rod. In some embodiments a cable-release system is used to receive released cable portions from the circular wheel and direct the released cable portions in an outward direction towards the cable release opening of the drum device, and prevent backward movement of the released cable into the housing. For example, and without being limiting, the cablerelease system may comprise a first cable-release unit mounted above the cable reel and having a slender opening defined between two rotatable roller shafts for passage of the released cable portions there through. Optionally, and in some embodiments preferably, the two rotatable roller shafts of the first cable-release unit are set with substantially different diameters according to a predetermined bend radius of the cable. The cable release system may comprise at least one additional cable-release unit having a slender opening defined between two rotatable roller shafts for passage of the released cable portions there through, where the at least one additional cable-release unit is mounted above and substantially in parallel to the first cable-release unit. Optionally, and in some embodiments preferably, orientation of the two rotatable roller shafts of the first cablerelease unit is substantially perpendicular to orientation of the two rotatable roller shafts of the at least one additional cable-release unit. In yet another aspect there is provided a controlled descent device comprising a wearable harness, a support structure attached to the harness and comprising a cable release opening for passage of portions of a spooled cable there through, and a drum device comprising the spooled cable and a brake mechanism configured to regulate the speed release of the cable from the drum device. In some embodiments the brake mechanism comprises a circular wheel configured to rotate about an axis of rotation thereof and having a circular central cavity, an axle extending along and rotatable about said axis of rotation inside the central cavity, two or more parallel shaft rods attached to the axle and extending substantially perpendicular to the axis of rotation inside the cavity, a gear system configured to transfer rotations of said wheel into counter- rotations of said axle, and one or more brake elements mounted on said two or more parallel shaft rods. Optionally, and in some embodiments preferably, each brake element has two or more pass-through bores for slidably moving along the two or more parallel shaft rods inside said central cavity. Two or more springs are mounted over at least one of the shaft rods between the brake element and the axle, and the one or more brake elements are configured to radially slide over the parallel shaft rods towards the inner wall of the wheel encircling in response to counter-rotations of said axle. The controlled descent device comprises in some embodiments a friction enhancement mechanism configured to increase friction forces between the brake elements and the inner wall of the wheel responsive to increase in angular velocity of the wheel. The friction enhancement mechanism is configured to provide additional engagement between the circular wheel and the brake element using one or more circular rails and corresponding one or more curved grooves engageable with the one or more rails, to thereby progressively increase friction between the brake elements and the inner wall of the wheel responsive to increase in angular velocity of the wheel. Thus, the friction enhancement mechanism further substantially facilitates prevention of suspension trauma to a descending user harnessed to the controlled descent device. In some applications the controlled descent device comprises a cablerelease system configured to receive released cable portions from the circular wheel and direct the released cable portions in an outward direction towards the cable release opening of the drum device, and prevent backward movement of the released cable into the housing. Optionally, and in some embodiments preferably, the cable-release system comprises first and second cable-release units mounted in parallel above the circular wheel, each cable-release unit having a slender opening defined between two rotatable roller shafts thereof for passage of the released cable portions there through.

Optionally, the orientation of the rotatable roller shafts of the first cable-release unit is substantially perpendicular to orientation of the rotatable roller shafts of the second cablerelease unit.

3.1 Gears

These are the essential machine elements designed to transmit motion, power from one mechanical unit to another. Various types of gears have been developed performs different functions.

Below are functions of gears

- Transmitting large power
- Transmit power at much higher speed
- Gives Higher speed ratios
- Wide range changes in speed ratios

Gears can be classified depending upon various factors. Generally they are

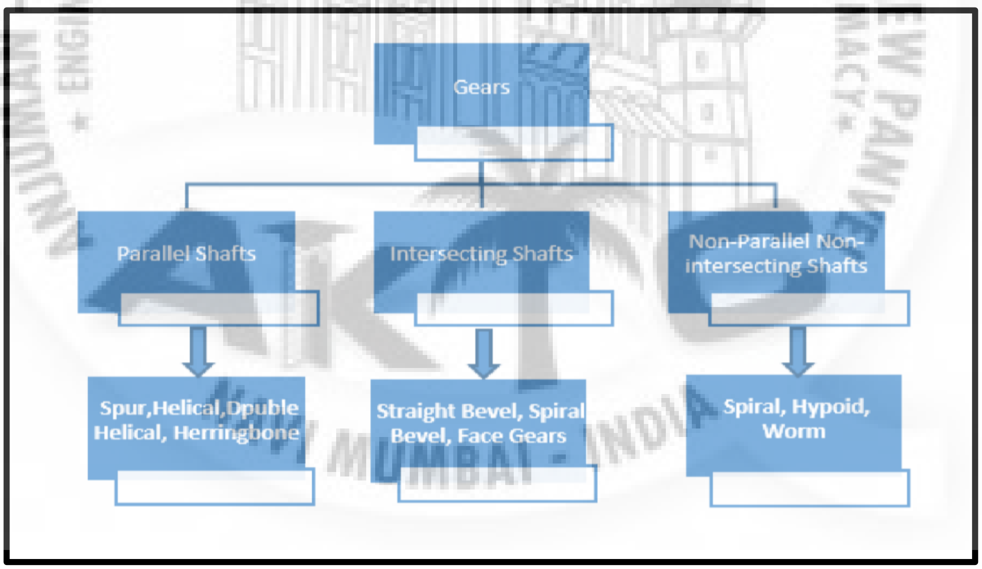


Fig 3.1 Classification of Gear

broadly classified as shown in fig 3.1.

3.2 Gear Materials

The satisfactory performance of gear pair depends upon the materials of the gear pair &their heat treatment. The desirable properties of gear materials are endurance strength in bending, low coefficient of friction, low & consistent thermal distortion, and sufficient surface endurance strength. Some of the materials used are as given below

- Cast irons
- Steels
- Non-ferrous metals
- Sintered metals
- Non-metals

3.3 Types of Gear tooth failure

Bending Failure or Tooth Breakage-

Gear tooth behaves like a cantilever beam subjected to repetitive bending stress. The tooth may break due to repetitive bending stress. Tooth breakage occurs when to repetitive bending stress induced in a gear tooth exceeds the bending endurance strength of the gear tooth. The tooth can be avoided by adjusting the parameters module & face width. Wear Failure:-

Wear is a phenomenon of which removes complete layer of the surface or makes craters or scratches on the surface. Different types of gears failures are discussed below. (1)Pitting (2) Scoring (3) Abrasive Wear (4) Corrosive wears

3.4 Design Specifications

Device "Controlled Fall Device for Emergency Rescue" developed with intention of controlling the speed of the rescuer by absorption of the excess energy with the help of the centrifugal brake mechanism and speed to require actuating the centrifugal brake is achieved with incorporation of the planetary gear box in the said unit. The free fall speed of the rescuer is utilized for actuating planetary gear box.

1. Maximum descending height – 120 m
2. Descend load – 135 kg (max)
3. Descend speed – 0.7 to 2 m/s
4. Product weight – 15 kg
5. No. of user – 1 per unit
6. Maximum Descending Speed - 0.8 to 2.0 m/s
7. Factor of Safety varies on the basis of the loading and dynamics of the component and it ranges from – 3 to 5

Descent energy, $W = m * g * h *$

W = Descent Energy , Joule m
= Test mass (Descend Load),
kg g = Gravity, 9.81 m/s^2 h =
Descent height m n = no. of
descent

Gear Calculations

Proper setting of the gear ratio of planetary gear system can be used to guarantee that the angular velocity of the cable reel does not exceed a predefined limit (150 rpm) and thereby guarantee that the descent speed remains within a predetermined range (about 0.8 to 2 m/s).

Table 3.1 Design Specification

Description	Symbol	Formulae	Values
Number of teeth on pinion	zp	-	18
Number of teeth on gear	zg	-	51
Pressure angle	αn	-	20^0
Module (mm)	m	-	4
Circular pitch (mm)	p	$p = \pi \times m$	12.566 3
Pitch circle diameter (mm)	dp	$dp = m \times z$	204
Addendum	ha	$ha = m$	4
height (mm)			
Dedendum height (mm)	hd	$hd = 1.25m$	5
Addendum circle (mm)	da	$da = dp + (2 \times m)$	212
Dedendum circle (mm)	dd	$dd = dp - 2 + \pi z \times m$	194

Base circle (mm)	db	db = dp × cos αn	192
Face width (mm)	F	F = 10 × m	40
Size of Element	Solution by conventional method	ANSYS result	% Accuracy
30	11827.2	11777	99.57
40		11386	96.26
50		13179	89.74

Gear Ratio:- 1:5

a) Face width=1Om (m=module) F.S.=1.5,Y=0.308

For Zp=18,C.S.=1.5

$$\left\{\frac{\{60*10^6\}}{\Pi} = \left[\frac{Kw*Cs*F.S}{Zp*n1*\left(\frac{Sut}{3}\right)\left(\frac{b}{m}\right)*Y*Cv}\right]\right\}^{\frac{1}{3}}$$

m= m

=

3.73≈

4mm

b) Beam strength (Sb) Sb = $\left(\frac{Sur}{}\right)$= 240N/mm2

Sb = 4×40×240×0.308= 11827.2 N

Epicyclic gear train: Gear type - spur gear

Ts – 18, Tp – 38 and Tr – 96

Pressure angle – 20˚ full depth

Drum speed = 110 rpm, Drum diameter= 175 mm

$V = (\Pi DN/60)$

V= 1 m/s

$$\frac{Ns}{Na} = \frac{Da}{Ds}$$

$$Ns = Na * \{\frac{Da}{Ds}\}$$

Ns= 550 rpm

$P = (2\Pi\,\mathrm{NT}/60)$

P = 19.77 kw

$$Tout = \frac{(30 * P)}{(\Pi * \mathrm{Na})} * \mathrm{I} * \mathrm{Ks}$$

T out = 2145.93 Nm

T out = 2145.93 * 3 = 6437.79 Nm

Spur pinion loads-

Pressure angle α = 20˚,

Break shoe

r1 : Brake band radius = 0.046 m r 2 :

Radial distance from G to 0 = 0.034 m μ1

p=Tangential force representing the frictional force on the shoe mr2ω2 =The radial mass acceleration effective force at G μ1= The coefficient of friction for the brake material

$\mu 1$=The coefficient of friction for the sliding element

l= length of shoe b= width of shoe p=
intensity of pressure exerted on shoe

$$Ps - Pc = F + l * b * p$$

L= RΘ (Θ = angle subtended by shoe at centre of rotation)

F = μ (Ps-Pc)= 770.085 = μ*m * 0.130 (769-246.49)

Mass of brake shoe m_b= 3.33 kg

3.5 Parametric Modelling of Gears

The modeling is being done by using CATIA V5R19 in which modeling of each individual parts along with its drafting is performed. All the parts are assembled by using bottom up assembly approach so as get the assembled effect of all the parts. So as to maintain the functional requirement of device the gears are specially designed by parametric modeling for easy to update and relative parts are modeled by using Boolean operations.

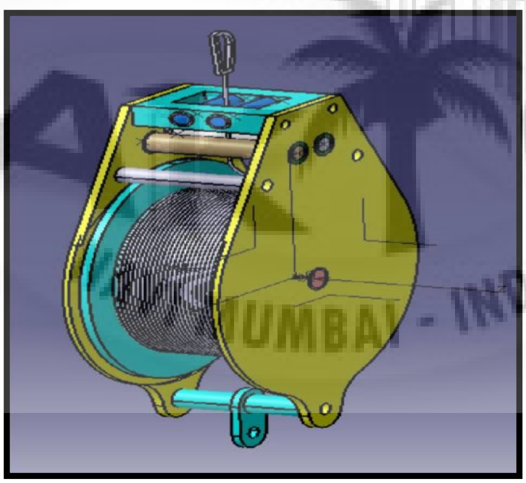


Fig 3.2 CAD model of assembly unit.

The figure 3.2 shows the cad model of the assembly unit in the isometric view which gives an overview for the actual assembled unit before manufacturing.

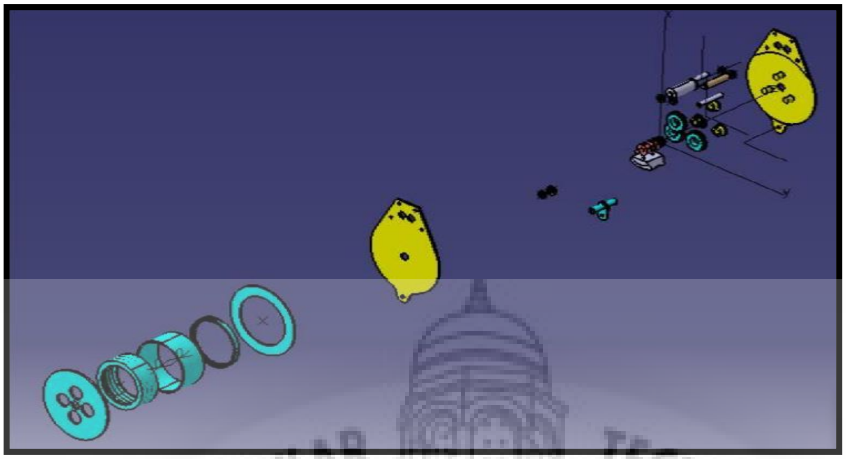


Fig 3.3 The exploded view of assembly unit.

Figure 3.3 shows the exploded view of the assembly so as to show the number of integral parts and the way they are assembled as per there function.

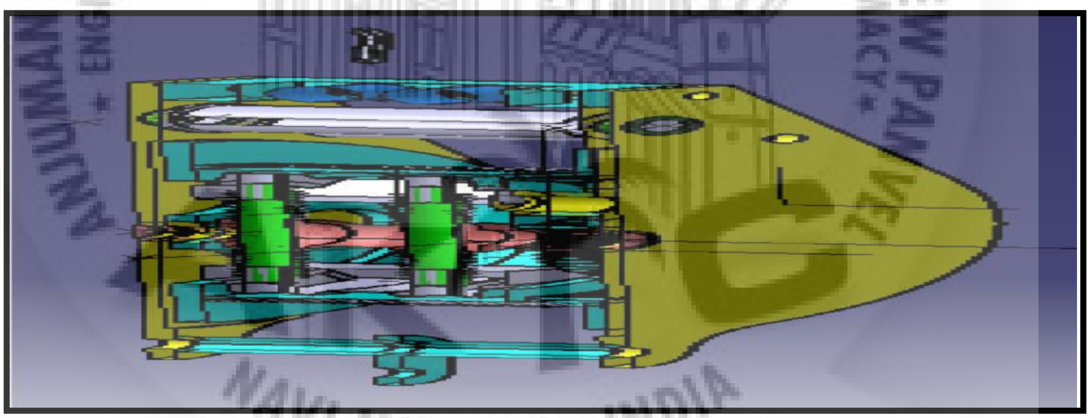


Fig 3.4 section view of assembly unit.

Figure 3.4 CAD model of assembly unit shows the section view of the assembly which is defined at the mid plane of the cad geometry to understand the working of the mechanism.

CHAPTER - IV

4. FE ANALYSIS

4.1 Basic Steps In Finite Element Method

In this finite element analysis the continuum is divided into a finite numbers of elements, having finite dimensions and reducing the continuum having infinite degrees of freedom to finite degrees of unknowns. It is assumed that the elements are connected only at the nodal points.

The accuracy of solution increases with the number of elements taken. However, more number of elements will result in increased computer cost. Hence optimum number of divisions should be taken.

In this chapter an analysis is made of the braking mechanisms to develop a theory which is validated in a subsequent chapter. There are three main designs considered, starting with a 4 shoe sliding brake and then proceeding with 2 and 4 shoe pivot brakes, with leading and trailing shoes. The analysis provide equations which relate brake torques to brake speed for all the brake shoe arrangements and the graphs obtained from these equations are compared with test results in the following chapter.

More analysis was carried out to provide equations which relate drop velocity to drop length, when using tape on a spool. These result in a high initial velocity, when the spool is full and a low final velocity, when the spool is empty. However, at the point that the evacuee makes ground contact then the evacuee is required to be moving at less than 2 m/s. The formulae given in this chapter give an analysis for each of the designs of brake that are considered. The diagrams show the forces and moments on each brake shoe in order to determine the brake torque developed. The brake shoe equations are then used to produce graphs of brake speed against torque for all the brake shoe arrangements. The final equations enable graphs to be plotted of drop distance against drop velocity and drop time against drop distance for a range of drop masses. These curves show that it is possible to control both the initial and final drop velocities by careful selection of the maximum and minimum spool radii. In the next section these theoretical results are compared with results obtained using the brake test rig and the drop test rig. In the element method the problem is formulated in two stages:

The element formulation

It involves the derivation of the element stiffness matrix which yields a relationship between nodal point forces and nodal point displacements.

The system formulation

It is the formulation of the stiffness and loads of the entire structure.

Steps In Finite Element Method

a. Discretization of the domain:-

The continuum is divided into a no. of finite elements by imaginary lines or surfaces. The interconnected elements may have different sizes and shapes. The success of this idealization lies in how closely this discretized continuum represents the actual continuum. The choice of the simple elements or higher order elements, straight or curved, its shape, refinement are to be decided before the mathematical formulation starts.

b. Identification of variables:-

The elements are assumed to be connected at their intersecting points referred to as nodal points. At each node, unknown displacements are to be prescribed. They are dependent on the problem at hand. The problem may be identified in such a way that in addition to the displacement which occurs at the nodes depending on the physical nature of the problem.

c. Choice of approximating functions:-

After the variables and local coordinates have been chosen, the next step is the choice of displacement function, which is the starting point of mathematical analysis. The function represents the variation of the displacement within the element. The shape of the element or the geometry may also approximate.

d. Formation of element stiffness matrix:-

After the continuum is discretized with desired element shapes, the element stiffness matrix is formulated. Basically it is a minimization procedure. The element stiffness matrix for majority of elements is not available in explicit form.

They require numerical integration for this evaluation.

e. Formation of the overall stiffness matrix:-

After the element stiffness matrix in global coordinates is formed, they are assembled to form the overall stiffness matrix. This is done through the nodes which are common to adjacent elements. At the nodes the continuity of the displacement functions and their derivatives are established.

f. Incorporation of boundary conditions:-

The boundary restraint conditions are to be imposed in the stiffness matrix. There are various techniques available to satisfy the boundary conditions.

g. Formation of the element loading matrix:-

The loading inside an element is transferred at the nodal points and consistent element loading matrix is formed.

h. Formation of the overall loading matrix:-

The element loading matrix is combined to form the overall loading matrix. This matrix has one column per loading case and it is either a column vector or a rectangular matrix depending on the no. of loading conditions.

i. Solution of simultaneous equations:-

All the equations required for the solution of the problem is now developed. In the displacement method, the unknowns are the nodal displacement. The Gauss elimination and Choleky„s factorization are most commonly used methods.

j. Calculation of stresses or stress resultants:-

The nodal displacement values are utilized for calculation of stresses. This may be done for all elements of the continuum or may be limited only to some predetermined elements.

4.2 Finite Element Models

The two dimensional models-
Fatigue or yielding of a gear tooth due to excessive bending stress is two important gear design considerations. In order to predict fatigue and yielding, the maximum stresses on the tensile and compressive sides of the tooth, respectively, are required.

When meshing the teeth in ANSYS, if ―SMART SIZE‖ is used the number of elements near the roots of the teeth are automatically are much greater than in other places. It also indicates that only one tooth is enough for the bending stress analysis for the 3-D model or a 2-D model.

Three dimensional models-

In this section the tooth root stresses and the tooth deflection of one tooth of a spur gear is calculated using an ANSYS model. For the bending stress, the numerical result is compared with the values given by the draft proposal of the standards of AGMA.

The element type ―SOLID TETRAHEDRAL 10 NODES 187‖ was chosen. Because ―SMART SET‖ was chosen on the tool bar there are many more elements near the root of the tooth than in other places. From the Lewis equation if the diameters of the pinion and gear are always kept the same and the number of teeth was changed, the diametric pitch will be changed or the module of gears will be changed. That means that there are different bending strengths between the different teeth numbers.

4.3 Analysis of Spur Gear Using ANSYS

Step 1:- Import the solid model from pro e:-File-import-IGES

Step 2:-Preference →Structural→ OK.

Step 3:- Preprocessor→

Selecting the element type for the gearPreprocessor → Element type →Add/Edit/Delete→ click on Add in the dialogue box that appears → In Library of Element Types select Solid-Tet 10node 187→Ok

Step 4:- Specifying the material properties

Choose preprocessor→ Material props→ Material Models→ Double click on

Structural→ Linear→ Elastic→ Isotropic. The Young‟s modulus of plain carbon steel is 2.1 E5 and the poisson ratio (PRXY) is 0.3. Choose preprocessor→ Material props→

Material Models→ Double click on Structural→ Density.

Density of plain carbon steel is 6.8e-6

Step 5:-Meshing the geometry

Descretize the model into finite elements. Set the element edge length to 30.

a) Meshing→ Size control→ Manual → Global→ Size→ Enter Element Edge Length as 30 → OK

b) Now mesh all the volumes in the geometry Step 6:-Applying load constraints

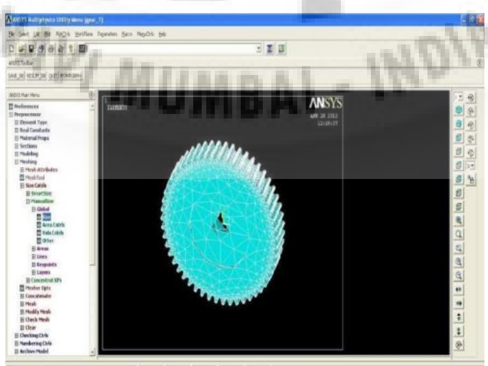
Loads→ Define Loads→ Apply → Structural→ Displacement→ On Areas→ Select the inner surfaces of the key hole→ OK

Step 7:- Solution

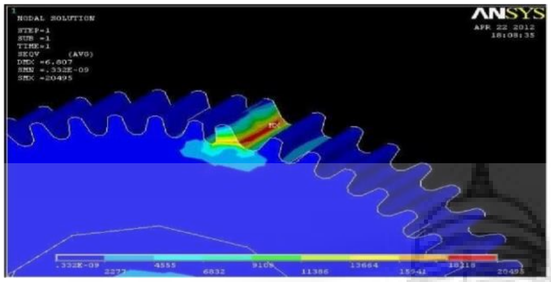
Step 8:-General Postprocessor

General Post procedure → Plot Results→ in the Plot Deformed Shape dialogue box select

Def + un-deformed→ General Post procedure→ Plot Results→ Contour Plot→ Nodal Solution→von misses stress→OK



4.1MESHING OF GEARS



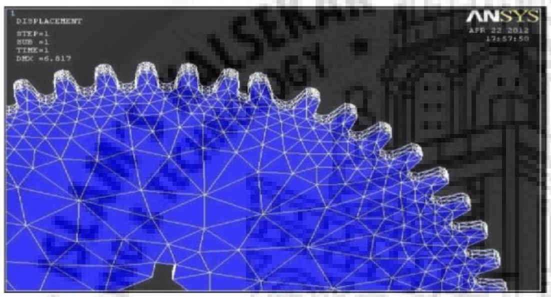


Fig 4.2 ELEMENT EDGE

Fig 4.3 GENERAL POST PROCEDURE

The analysis is done by using CAE software – ANSYS R19.2. The analysis is done by consideration for the whole assembly along with individual parts. Auto meshing is preferred for generating mesh. Number of nodes – 77761 generated and number of elements – 16589.

4.4 Analysis Of Assembly Unit

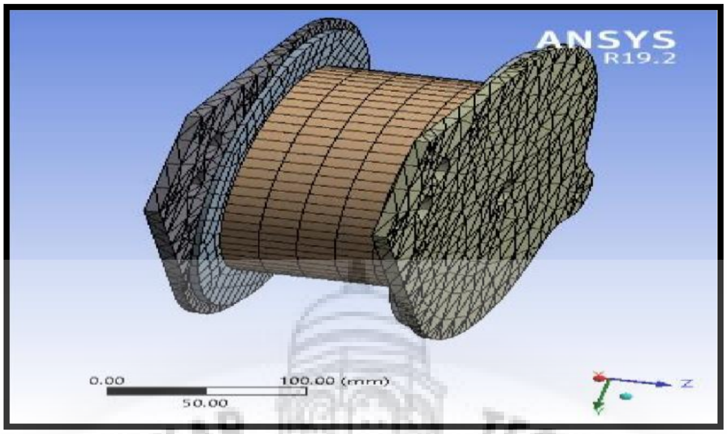


Fig 4.4 Mesh model in Ansys.

The Fig.4.4 shows the mesh model in ansys. The next step to apply boundary conditions i.e constraints the side mounting plates are the fixed elements of the assembly and the roller upon which the wire is rolled is applied by bearing load as shown in fig. 4.5.

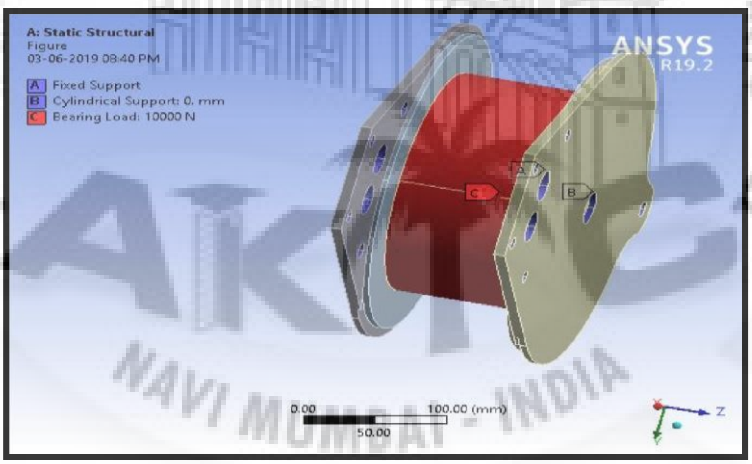


Fig 4.5 Results of Analysis after applying bearing load

Static structural analysis is performed and the max von mises sressess generated are recorded as 37.626 Mpa as shown in figure 4.6.

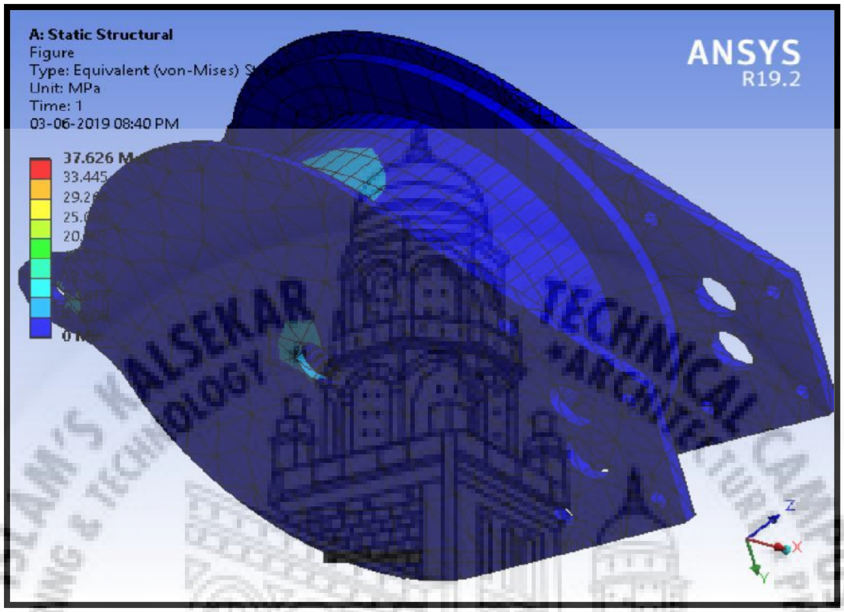


Fig 4.6 Results of the structural analysis

Total deformation is also shown in fig.9 as below as the max deformation is possible to occur at the outer edges of the plate.

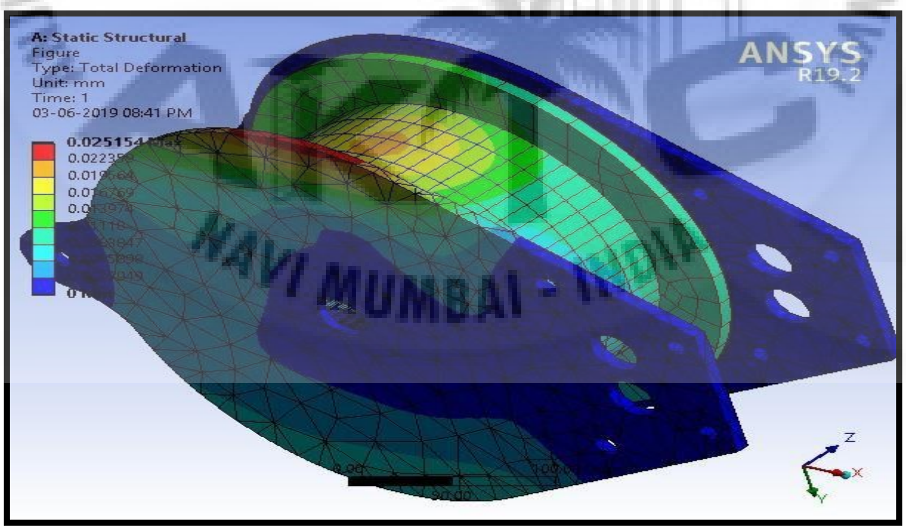


Fig 4.7 Total Deformation

4.5 Wire Rope Lifeline

The descent control design can continue along several routes. If the height is less than 20 m height it may be advantageous to utilize a wire rope as the lifeline. This could develop into a self rewinding design for multiple evacuation or recreation with no trailing lifeline and the ability to fast rewind due to the selection of wire rather than tape or fibre rope this type of design would cover a number of potential risks or evacuation needs. In order to achieve the minimum tensile requirements for designs for mass evacuations the wire would have to achieve 12 kN in tensile strength in order to meet the current and envisaged International standards that are written or being developed subject of PrEN. Wire, depending upon construction would require a minimum bend radius of between 10 and 20 (ratio i.e. 10 d to 20 d where d is the diameter of the wire rope in mm) as a multiple of the diameter. The wire diameter should be kept as small as possible and from a review of wire rope supply data (Bruntons of Scotland guide used) this indicates a diameter of 4.1 mm (nominal 5 mm) would be required. In order to keep the design as compact as possible the construction of the wire would also be important, reducing the size of the drum required and also reducing the internal friction which would impact upon the rewind mechanism. A 3mm wire diameter is used as shown in figure 4.8 similarly for attachment a wire rope sling is shown in figure 4.9.

Fig: 4.8 Galvanised iron wire rope

Fig: 4.9 Wire rope sling for attachment.

From studying the supply data from several wire manufacturers the optimum construction for the lifeline would be 6 x 19 (six core with 19 strands of wire per core) with a fiber core as this would allow a minimum bend radius of 10 times the diameter to be applied. If the design were to move to a single use with no rewind, then the wire rope diameter could be decreased to 3 mm as the strength requirement for such designs set by the International standards is 5 kN. With the reduced diameter and continuing the minimum bend radius of 10 times the wire rope diameter the design would either be smaller and more compact or the design would be capable of holding more lifeline permitting greater descent heights to be achieved. Also the lack of a rewind mechanism would assist the design size and shape. The other disadvantage with designs that use wire rope is its weight. Compared to fiber rope a 5 mm diameter wire rope weighs typically 90 g/m compared with 9 mm diameter fiber rope 50 g/m and tape which typically weighs 8 g/m.

4.6 Tape Lifeline

Tape life line is to be only studied as an optional case in the device. In light of the potential heights that has to be evacuated the use of a tape as the lifeline has many advantages such as very light weight and minimal bend radius for storage and compactness. The issue over strength and termination were examined with solutions found. The ability to pack 100 m of tape onto a very small drum offers designers another option, moving away from wire rope or fiber rope to provide a lightweight tape unit that is suitable for safe and simple inclusion in a means of descending. The tape does not rewind easily and the environmental issue of sun degradation has to be considered in any design put forward. However, the tape developed for this study with a thickness of 0.65 mm and a weight of only 8 g/m is significant advances. The termination of tape proved to be a particular problem as congenital sewing machine set up and existing threads failed to meet the requirements. The clamps developed for the machining and the Zylon thread solved the issues encountered and repeatability was achieved. Further work relating to mass evacuation is still to be carried out but the tape is considered to be an alternative to wire and fibre ropes due to its inherent advantages. Figure 4.10 shows the tape lifeline.

Fig 4.10 Tape lifeline

CHAPTER-V

CONCLUSION :

The parametric model is capable of creating spur gears with different modules and number of teeth by modifying the parameters and regenerating the model. Sets of gears having the same module and pressure angle can be created and assembled together. It is possible to carry out finite element analysis such as root bending stress and contact stresses between gear teeth pair and effect of root fillet radius on the root stresses. In this paper, a 3D deformable-body (model) of spur gears is developed. The result is checked with theoretical calculation data. The simulation results have good agreement with the theoretical results, which implies that the deformable-body (model) is correct. This study provides a sound foundation for future studies on contact stresses. The model is applied onto commercial FEA software ANSYS. Simulation results were compared and confirmed by the theoretical calculation data. According to these results, we can draw the conclusion; it was found out that the numerically obtained values of stress distributions were in good agreement with the theoretical results. A number of designs have been developed as part of this research. The designs have been validated by mathematical analysis. What has emerged is the ability to utilize a number of descent options depending upon the environment and application. This has implications in rapid evacuation from high rise structures. Design of personal evacuation device using controlled descend technology with planetary gear and centrifugal braking system for emergency single rescue has been carried out successfully and achieved controlled speed of less than 2 m/sec. The designs have been validated by mathematical analysis. Initial descent speed is greater than current standards permit but the ground contact speed of 2 m/s is achieved within those same standards. The descent speed reduced as the webbing paid out as predicted, offering the potential to use spooling where by higher descent speeds at the initial stages can be used to descend from greater heights in shorter time periods as set out in the objectives. This research offers reference designers, in order to design descent controllers for a wide range of applications and conditions.

Future scope :

Personal evacuation and mass evacuation systems are predicted to be a fundamental consideration for buildings and structures in the future. This is due in part to the demand for higher rise accommodation and work areas caused by land shortage and cost implications. This is driving the need for more solutions to be developed for descent systems. In addition, the advent of high profile terrorism, now considered a fact of modern living, will move forward the use and research of descent devices and systems as engineers of the future work on the problems associated with evacuation from height. The next stage in the development of the personal descent controller and the basis of future work is to investigate how mass evacuation is achieved using the brake mechanisms and lifelines developed here, including the use of cartridges that can be used to affect multiple descents. Future work would also include alternative braking methods with the descent controlled by hydraulics or pneumatics. Work on the position of strong anchorage points on the structure for evacuation, in addition to the use of lift shafts or blow out windows would form part of future work. This would integrate descenders with other equipment such as smoke hoods or guided escape methods. This work would allow for the inclusion in new technology, which presents new demands, such as wind farms, leading to an expanded scope for future work.

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