

# Accelerating the development of marine energy engineering



## Contents

- Variable Reluctance

The old subdivisions have shown the potency for the feasibility of Ocean energy devices and a mentality that SKF will hold to judge its bearing monetary values in the hereafter. The clear indicators that there still are major technology and economic plants and challenges in front to get the better of before ocean energy device are deemed to be commercially deployable have been based on a batch of premises and uncertainties. These challenges can be considered to impede the development of the marine energy sector. In this undermentioned subdivision, the expression into how the challenges can be tackled by all makers can assist speed up the engineering [ 37 ] :

Copied ( if possible merely twosome of sentences per point )

-Design assortment and consensus: Marine energy invention activity is spread over a broad assortment of constructs and constituents. Over the shorter term, the deficiency of design consensus in both moving ridge and tidal current energy engineering fields is likely to curtail the gait of development and acquisition. At the same clip, there may be important longer-term advantages from retaining design assortment.

-Parallel support for incremental and extremist invention: closest-to-market large-scale moving ridge and tidal current paradigms ( of around 1 MW units ) utilizing more conventional designs and constituents receive the majority of fiscal resources and invention attempts across the sector as a whole - particularly from the private sector. While the testing of these more

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mature paradigm designs is critical to capture learning-by-experience, there is a parallel demand to back up invention in more extremist options which may enable step-change public presentation betterments and/or cost decreases over the longer term. Given the longer timescales for this more extremist invention, public support has a continued prima function to play here.

-Feedbacks between learning-by-doing and learning-by-research: because of the early phase of marine energy engineering development, there is presently merely limited experience in existent operating conditions. One facet of accelerated development is the feeding-back of informations and experience on paradigm public presentation and runing experience into earlier stages of the invention concatenation. In pattern, the transportation of experience is likely to be limited by commercial competition.

-Shared acquisition for generic engineerings: there are a figure of ' generic ' engineerings and constituents which have application across the sector, such as foundations, moorages, marine operations and resource appraisal. While these offer chances for shared/collaborative acquisition, the support and transportation of generic cognition and constituents are limited by commercial competition.

-Knowledge and engineering transportation from other industries: other industry sectors, such as, but non limited to, offshore technology and offshore air current, offer potentially of import chances for cognition and engineering transportation. Enabling this transportation depends in portion on a better apprehension of the ' adaption costs ' - the costs of reassigning

constituents and methods to the Marine context – and besides, placing and taking advantage of specific chances for coaction with other industries or supply concatenation spouses

The advancement of Marine energy engineering is extremely unsure, and like all scenarios describe in the old subdivision, the scenario of accelerated Marine development devised here is extremely sensitive to premises sing capital cost and proficient public presentation. As such, the Marine scenario provides one possible development tract, presuming high but plausible degrees of technological advancement. Repeating that to accomplish the high and sustained degrees of invention and acquisition assumed depends on making and prolonging a extremely effectual Marine energy invention system, the chief inside informations of this system will non be elaborated farther. But may function as guidelines to back up SKF in the future determination devising, and how it will impact its deduction and growing in the market. In pattern there are a important proficient, economic and institutional challenges involved in supplying this.

Copied: In the short term ( up to 2020 ) there are considerable deployment challenges, including planning and statute law, accomplishments deficits and handiness of installing vass. Another challenge may be related to rational belongings protection. Despite a degree of headway, grid support may besides go a important challenge during this period. Over the following decennary, the cost decreases embedded in the Marine scenario are predicated on niche-learning, with progressive cost decrease and design consensus, as a little figure of ‘ first coevals ‘ moving ridge and tidal device designs become de facto ‘ industry criterions ‘ . In this scenario, there is <https://assignbuster.com/accelerating-the-development-of-marine-energy-engineering/>

besides likely to be a consolidation of developer houses, as amalgamations and acquisitions bring together some little developers and let loanblends of the best engineerings to emerge and cut down costs. Over the longer term ( after 2035 ) , it is implausible to depict the way of marine energy invention in any item, but accomplishing the sorts of sustained acquisition that are embedded in the Marine scenario is likely to necessitate the debut of ‘ second coevals ‘ engineerings capable of more efficient resource extraction and transition. In the interim, there is a demand for support steps and policy schemes which allow more unconventional and riotous engineerings to be researched, developed and tested. Supporting RD & A ; D on more extremist and higher hazard engineerings is an of import enabler of invention over the longer term, and there is an of import function here for publically funded long-run R & A ; D programmes.

Prolonging the acquisition assumed in the Marine scenario over the long term will besides necessitate the development of a much more internationalised Marine energy industry - and associated invention system - over the medium and longer footings.

Institutional and infrastructure barriers ( such as supply concatenation restraints, be aftering restraints and grid support ) may hold been mostly addressed in the long term. However, resources in deeper Waterss or more hard locations may go exploitable by this clip, showing new proficient or substructure challenges. In add-on, competition for stuff and fiscal resources from other energy and non-energy sectors could enforce longer-term restraints on the sector [ 37 ] .

## Benchmarking of Ocean Energy Devices

Mentioning back to the SKF theoretical account, the following measure in our scheme was to place all the proficient facets environing the Ocean Energy engineering. In fact in this subdivision the benchmarking of the devices will enable SKF to place prima device makers in both Tidal and Wave energy engineering.

### Figure 2: Challenges for long-run endurance of Ocean energy devices

The undermentioned subdivision will enable to cast some visible radiation on standards that will be used for the benchmarking of moving ridge and tidal devices coupled with the premises presented in the old subdivisions. Figure 31 illustrates the chief challenges that device makers need to confront for a possible long-run endurance in the industry. The challenges are non meant to be thorough nor a rigorous guideline, nevertheless get bying with these challenges will ease the successful long life of the devices [ 45 ] .

Copied: The primary wave-body interface is a good wave-maker:

It is of import that there is a strong yoke between the fluid gesture in the close field boundary around the device and the far field fluid gesture which is associated with wave action in the most commonly happening seas. This consequences in an efficient moving ridge power extractor as there is a mutual relationship between moving ridge coevals and soaking up. However, as the gesture of the organic structure becomes greater it should increasingly cut down its ability to bring forth moving ridges. This means that as the seas get larger the traveling organic structure increasingly decouples

from the moving ridge induced unstable atom gesture therefore restricting the sum of power that has to be converted.

The device can avoid utmost loading in storms:

Apart from progressive decoupling as the sea province increases the device needs to be able to travel to a ' fail safe ' status in which it wholly avoids the extremes of moving ridge burden in storms. This is a ' last resort ' scenario as ideally it is desirable for a device to go on production in storms due to significant uncoupling from the moving ridges. It is non economic to supply construction to defy utmost tonss as it is merely required for a really little per centum of clip and chiefly lies redundant.

The device has an appropriate wide bandwidth response:

The device should hold a good power gaining control over the scope of most normally happening incident moving ridge frequencies it is subjected to. In a physical system, reactive energy is stored as kinetic and possible energy, whilst the active power is related to power gaining control and radiated power. At a system ' s natural frequency the fluctuation in reactive energy is zero, as the incident moving ridge force and the speed of the on the job surface are in stage. Thus for a wide bandwidth response the device kineticss must guarantee that this is mostly achieved over a scope of frequencies and there is a assortment of agencies to make this. For illustration, by holding two or more natural frequencies within the moving ridge frequency range the responses from them can unify to give a wide bandwidth. This can be achieved with ' harbours ' in forepart of hovering

H2O columns ( Count & A ; Evans 1984 ) . Alternatively ' slow tuning ' can be <https://assignbuster.com/accelerating-the-development-of-marine-energy-engineering/>

adopted where the stored kinetic or possible energy is adjusted with sea-state so that even with a narrow bandwidth the natural frequency of response is centred on the incident moving ridge frequency to maximize public presentation. Finally so called ' phase control ' or ' complex-conjugate control ' can be used in which the kinetic or possible energy is manipulated on a wave-by-wave footing to maximize public presentation ( Budal & A ; Falnes 1980 ; Salter et Al. 2002 ) .

the device is non site specific and can be mass produced

These factors minimise production and design costs. From experience of the two paradigm moving ridge energy convertors on Islay the sums of outgo required to plan and attest bespoke constituents are significant, doing site-specific versions highly unwanted. The usage of mass production techniques has the potency for dramatic decreases in cost, peculiarly in the power take-off constituents. This implies that other device elements should be modified so that they are sized appropriately for a mass-produced faculty.

Dependability of the constituents will besides increase with mass-production because of the increased attempt in design and experience gained in their usage.

the device has short direct burden waies:

The usage of short, direct burden waies is a good known design rule and is clearly of relevancy to the design of moving ridge energy convertors where big forces have to be transmitted. This influences the size and cost of structural elements in the device. For moving ridge energy convertors the



burden scenario is complicated because of the inherently oscillatory and distributed character of the incident moving ridge force.

Either the whole device or serviceable constituents are easily removed.

Working at sea is basically more expensive and more risky than working ashore. Furthermore, the sea-state may badly restrict the times that the device is accessible for servicing therefore cutting down handiness. With seabed-mounted devices it is desirable that all the constituents which are likely to necessitate attending are demountable for servicing back at base. This implies an inactive non-serviceable portion of the device remains at site. This is likely to hold the extra benefit of doing installing an easier operation.

Floating devices should be easy to decouple from the moorings and power take-off connexion and be towed into dock.

The challenges set above should be considered as a guideline in future developments of new devices and as a partial appraisal of taking makers of ocean energy devices to develop and see the long-run survivability of their devices. However the judgement based on these standards 's is really complicated as publications from makers is really limited, due to the precautionary steps and the competition since this discovery engineering. In fact, the probe led by the Renewable Section at SKF has led to the finding of more so 240 device developers for both Tidal and Wave energy devices [ 46 ]. Further these probes lead to demonstrate that all the research workers and developers have different constructs and designs and are in different testing and development phases [ 2 ] [ 47 ]. Thus to be able to compare those devices harmonizing to the simplified benchmarking technique, the set of

common evidences for rating were established based on the economical and development of those devices. With the Renewable Section at SKF, “ success factors ” were determined have a first overview of taking devices makers and every bit good as to what type of device they are developing harmonizing to the list described in the old chapter [ 2 ] [ 46 ] [ 47 ] .

Table 1: Scaling Table

## **Points**

### **Development experience and position**

### **Technology characteristics**

### **Fiscal support and future chances**

### **Joint Venture/Co-operations**

### **Expected Coevals Costss**

#### **10 to 8**

Developer with ocean energy experience for more than 10 old ages, full graduated table paradigm developed or commercial possibility ( little farms ) available

Maintainability, rapid installing, readily available parts, withstands conditions, particular berthing systems and appropriate coevals costs

High backup from private investors, authorities finacess and inducements, big graduated table or little graduated table planned for operation boulder clay 2020

High profile spouses in development, joint ventures for deployment and proving available

Presentation of paradigm, CoE can make degree compared to other renewable after deployment of scaly undertaking

## **8 to 6**

Developer with ocean energy experience for more than 5 old ages ( & It ; 10 ) , full graduated table paradigm developed or commercial possibility ( little farms ) in the following 3 old ages

Technological characteristics are less outstanding so taking devices

Available support from private investors and endorsing from authorities and planning to deployment operation in the following 3 old ages

A noteworthy spouse for their development and joint ventures for deployment and proving available

CoE is expected to vie with off-shore air current from early coevals

## **6 to 4**

Developer with ocean energy experience for less than 5 old ages, and is in advanced phase of design

A twosome of technological characteristics constitute the device

Investigating fiscal support possibilities and planning of presentation of paradigm

Manufacturer seeking development spouses

CoE after deployment might be able to vie with high CoE monetary values of off-shore air current energy

## **4 to 0**

New developer with really small experience in the ocean energy market and is still in concept phase or the development of the engineering has come to hold

Technological characteristics minimal or unknown/not disclosed

About no fiscal support and future undertakings are non planned.

No development spouses

CoE can barely be determined and can be expected to be much greater than other renewable energy devices. According to the factors listed in the tabular array above, burdening have been set to separate the importance of factors relative to others. The burdening follow extended treatment within SKF and literature published to optimise judgement on taking or top acting device developers ( Table 10 ) .

Table 2: Standards and their several factors

## **Factors**

## **Weight**

## **Development Status and experiences**

0. 2

## **Fiscal support and future chances**

0. 3

## **Technology characteristics**

0. 2

## **Joint Ventures**

0. 15

## **Expected coevals costs**

0. 15

Benchmarking Of Wave Energy Devices:

The tonss and weightings for each device are found in the Appendix, the benchmarking of moving ridge energy devices has been done on the footing of rating of top acting devices. The cardinal importance of this benchmarking is to reflect the type of devices that SKF has to react to for direct engagement in the market. The benchmarking should be used as one key factor for rating of possible supply of SKF plain bearings at first glimpse and as a five-platform provider.

Table 3: Top Wave Energy Converters

## **Rank**

## **Manufacturer**

## **Mark**

### **1**

Pelamis

7. 91

### **2**

Aquamarine Power

7. 34

### **3**

Ocean Power Technology ( OPT )

6. 92

### **4**

Ocean linx

6. 84

### **5**

Wave Star

6. 76

### **6**

Wave Bob

6. 12

Table 11 shows Pelamis and Aquamarine as chief developers as they are the lone two makers that are continuing in the commercial stage, and are developing new engineering to remain at the head of the market of moving ridge energy [ 30 ] [ 32 ] . Another point to be drawn out which complies with all the old theoretical accounts and statements is that out of the top six prima devices four are portion of the greater household of point absorbers ( table 12 ) .

Table 4: Categorization of top Wave Converters

## **Attenuators**

## **Exterminator**

## **Point Absorbers**

### **– Pelamis**

- Aquamarine Power Oyster

- OPT

- Ocean Linx

-Wave Star

-Wave Bob

The potency of point absorbers can be evaluated based on the definition of each device at first. The definition of each class has shown that attenuators are influenced by the length of the incident ( period  $T$  ) wave to bring forth

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energy, whilst eradicators are widely influenced by the amplitude of the incident moving ridge to bring forth energy. However for the point absorber the influence is both the period and the amplitude of the moving ridge that will act upon the energy coevals. This appraisal is based on the definition of each class. Furthermore, the potency of point absorbers can be reflected as to their CoE, since their draw construction and size is comparatively much smaller in comparing with eradicators and point absorbers, the CapEx would comparatively be much smaller, holding a relative influence in the decrease of the cost of electricity. The end is non to demo the advantages of a class against the other, but as a provider to this industry it is critical to cognize where the focal point on development should be on short term, for direct deduction and puting a tendency for long term.

Benchmarking of Tidal Energy Devices:

The same weightings have been used for the benchmarking of tidal energy devices and the tonss are attached in the Appendix. The top developers in the field of tidal energy are listed in Table 13 below.

Table 5: Leading Tidal device makers

**Rank**

**Manufacturer**

**Mark**

**1**

Marine Current Turbines

9. 70

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**2**

Open Hydro

9. 51

**2**

Atlantis Resources Corp.

9. 51

**3**

Voith Hydro

9. 30

**4**

Tidal Energy

8. 60

**5**

Hammerfest Storm

8. 16

In the instance of tidal energy devices, no distinguishable household can be drawn out, apart from the fact that all devices are horizontal axis turbines, as they seem to outclass perpendicular turbines in their end product efficiency every bit good as in their ability to run in much greater size and defy the conditions of the ocean. This can be closely related to the initial

developments on air current energy turbines, in its early phases the abundant figure of turbines have been designed from different types of perpendicular axis turbines to the normally used horizontal three blade turbines of today [ 48 ] .

### Energy Devices Viewed by SKF

The undermentioned subdivision sits within the SKF direction scheme and helps research and place further the proficient section established. The subject of this subdivision is to seek and convey out the possible deduction of SKF, and more specifically apparent bearings in such applications. This designation is the consequence of the apprehension that no individual device operates and possesses the same engineering as any other [ 3 ] [ 13 ] . However as a first appraisal sing the classs can convey out a rating of demands for each class.

### Bearing Applications in Ocean Energy

In this subdivision an overview of each class is reviewed with an illustration of device maker for this application, as an effort to convey out the bearing applications required for each class. The survey is in no manner conclusive and applicable to all devices to each class but as an inductive logical thinking through the prima devices a tendency can be evaluated as demands for SKF every bit good as demands for the device makers.

### Wave Energy Converters

Exterminators: Aquamarine Power Oyster:

Aquamarine Power is in the development of their 3rd coevals wave energy convertor device, called the Oyster 800 ( Fig. 32 ) [ 49 ] . The convertor will bring forth an estimation 800kW as its name suggests by pull outing the energy from the rush of the incident moving ridge [ 32 ] .

#### Figure 3: Oyster Wave Energy Converter

The Oyster energy convertor from Aquamarine Power captures the energy from the incident moving ridges in close shore through a pump that is controlled by the moving ridge rush gesture and enables to compact H<sub>2</sub>O. The hard-hitting H<sub>2</sub>O is driven into a hydroelectric turbine situated onshore [ 32 ] that will change over that energy into electricity. The Oyster can be considered as a mega construction ( Fig. 32 ) hinged to the ocean floor, it is a floaty construction where a hinged flap is attached to the anchored construction at deepness around 15 metres. The hinged flap is about wholly submerged under H<sub>2</sub>O and reciprocates rearward and frontward in response to the moving ridge spectrum and amplitude.

#### Figure 4: Simplified Drawing of Oyster device

The nexus between the flap and the chief stiff construction is our cardinal focal point, the reciprocating motion can merely be operate threw a bearing that enables the gesture of the flap. Figure 33 shows the location of the bearing location at the baseline of the flaps. The bearing seems important for the proper functionality of the application, as the construction should defy high impact tonss of the incident moving ridges.

#### Figure 5: Tonss subjected on the Bearing

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The bearing will hold to cover with chiefly radial tonss, and some sway tonss. As the tonss on the flap are non uniformly distributed, the bearing will hold to enable the smooth running of the one-degree of gesture device.

The general observations on eradicator devices show similarities in working rule from the first original design of the Pendulor in Japan ( Fig. 35 ) [ 50 ] .

#### Figure 6: Preliminary Design of the Pendulor

The size and operating conditions of the bearing are important and normally require bearing provider to work outside their offered catalogue.

A proposed solution to the high tonss and writhing minutes that are created on the flexible joints due to the none unvarying loads that the bearing are subjected to is to utilize a spherical field bearing that will be able to lean and rectify writhing minutes alignment both hydraulic random-access memory for smooth operations whilst defying the heavy tonss of the construction. The usage of bushings in this type of application can be considered due to the big concentrated burdens on the flexible joints, due to the weight of the construction and the impact loads on the flaps, nevertheless it is cardinal to gauge the burdens on the appendages of the bushings as they can non defy the same conditions as they center opposite number, the usage of washers can assist cut down weariness on the appendages of the bushings nevertheless the other issue would be to take into consideration the distortion minutes caused by the flap on the flexible joint and if the bushing could digest a certain bending for smooth operation.

Attenuators: Pelamis:

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The Pelamis wave energy convertor is the taking device in the attenuator class. The root of the word Pelamis is Latin for snake. The draw construction resembles to a drifting sea snake [ 30 ] .

Figure 7: Schematic of Pelamis ( 2 grades of freedom )

COPIED: The Pelamis machine is made up of five tubings subdivisions linked by cosmopolitan articulations which allow flexing in two waies. The machine floats semi-submerged on the surface of the H2O and inherently faces into the way of the waves. A As moving ridges pass down the length of the machine and the subdivisions bend in the H2O, the motion is converted into electricity via hydraulic power take-off systems housed inside each articulation of the machine tubing, and power is transmitted to shore utilizing standard subsea overseas telegrams and equipment [ 30 ] .

Figure 8: Hinges and bearings of Pelamis

The two-degree of freedom gesture is controlled by bearings that have to defy the reciprocating gesture of each member go forthing the axial tonss to be considerable compared to eradicators devices. As quoted by Senior Engineer and Bearing Group Leader at Pelamis that their “ biggest challenge has ever been [ on how to ] pull off the tonss and gestures from such an active and invariably variable environment, whilst at the same clip pull outing every bit much power as possible. The on the job forces generated across each articulation can be several hundred metric tons, which can show immense jobs for the bearings as they have to take up the reactive forces coming back through the articulations ” [ 52 ] .

The bearings have important functions in attenuators, as they are cardinal for the efficiency of the device. Smooth running bearing can maximise the end product of the Pelamis or any other attenuators by minimising stick faux pas and minimising frictional losings. The consequence of reciprocating tonss and changeless alteration in way, the bearing will hold to cover with both high radial and axial tonss, go forthing a suggestion of the favourable usage of spherical field bearings that will enable to defy to some extend the tonss and hovering frequence of these devices.

#### Point Absorbers:

It has been defined that point absorbers showcase different working rules so attenuators and eradicators. Point absorbers are divided in different subfamilies, the taking devices OPT, WaveBob, WaveStar and OceanLinx all present similarities but use different engineerings to reap the energy from the moving ridges.

#### Figure 9: WaveStar, Point Aborber

The Wavestar machine draws energy from wave power with floats that rise and autumn with the up and down gesture of moving ridges. The floats are attached by weaponries to a platform that stands on legs secured to the sea floor. The gesture of the floats is transferred via fluid mechanicss into the rotary motion of a generator, bring forthing electricity.

The bearing application in such devices show similarities as eradicators, as the drifting organic structure reciprocates linearly due to the alteration in moving ridge highs the bearing oscillates consequently whilst transporting

the tonss subject from the arm and the natation setup. The proposed is the possible usage of a bushing for such application as the major burden will be the inactive burden of the hinged arm with the hydraulic random-access memory ; nevertheless this proposal can be merely examined if the weaponries are in the way of the incident moving ridge. As to state in the instance of the moving ridge being perpendicular to the weaponries daze tonss will do higher flexing minutes on the arm and make comparatively higher axial tonss that a bushing will non be able to defy. The importance to gauge the way of the moving ridges is of import for the cost effectual usage of bushings, nevertheless a spherical field bearing will be able to defy all those unwanted conditions on bushings and restricting the demand to worry of unwanted radials tonss being able to pull out beckon energy from all types of incident moving ridges.

On the other manus, OPT and WaveBob have similar working principals creates electricity from the perpendicular gesture of the float relation to the stationary spar [ 54 ] . This gesture drives a mechanical system coupled to generators and produces AC electricity [ 55 ] . The electricity is rectified and inverted into grid-compliant AC, which has been certified to international interconnectedness criterions [ 56 ] .

The bearing criterions in such devices depend chiefly on the power take-off system ( Table 14 ) .

Table 6: Bearing Loads on different types of Point absorbers take off systems

**Group**

**Machine**

**Air-gap**

**Loading**

**Design**

**Integration**

**Shear force**

**Synchronous**

Field Wound

Autopsy

5mm

5mm

Large magnetic attractive force

Flat surfaces big active country

In air spread

Outside air spread

Low

**Air-Cored**

C-GEN



PM Tubular

5mm

5mm

Subjected to have weight

Within air spread along axial length

Long surface between poles

Low

High

## **Variable Reluctance**

Strontium

VH

TF

~1mm

~1mm

5mm

High magnetic attractive force

Long and thin topology

Outside with poles

On stator

Low

High

High

Table 15 summarizes the three different types of electric generators that may be found in point absorbers.

Table 7: Illustration of types of electric generators

Synchronous [ 58 ]

Air-Cored [ 59 ]

Variable Reluctance [ 60 ]

Copied: Linear bearings are used in applications such as conveyance within mills, milling machines, assembly lines, lifts, forklifts, preciseness mensurating equipment and in many actuators. Linear gesture can be catered for utilizing skidding passenger cars on usher tracks. The passenger cars have constitutional reciprocating ball bearings, roller bearings or kick polymer surfaces to run against the steel rail. These assortments of additive ushers and profile tracks are widely manufactured by companies such as SKF, Rexroth Bosch Group, INA Schaeffler Group, Hepco and IGUS.

The type of bearing mechanism is chosen depending on the torsion, burden capacity, velocity and life rhythm of the application. This type of bearing would be applicable to the design of a WEC as the ushers could maintain the traveling transcribers on a stiff, consecutive way. A sliding device would run most efficaciously, viz. due to the developement of difficult erosion, scratchy immune polymers such as those from Glacier Garlock Bearings and Deva-tex, Deva ( 2010 ) ; GGB.

Roller paths require certain compartments, good lubrication, a return way and low tonss for a long life span. If illimitable gesture ( e. g. milling machines ) , that is required, additive ball ushers, additive bushings and additive peal ushers are the most suited as they wear easy. For limited gesture, i. e. microscopes or preciseness mensurating devices with high velocity gesture, crossed roller bearings or stroke rotary bushings provide the really accurate motion due to their tight tolerances but with a lower life span due to maintenance demands [ 61 ] .