

Neuer Trend: 3-reihige Rollenlager für lastbasierende Blattverstellung



Referent: Werner Schröppel, IMO GmbH & Co. KG



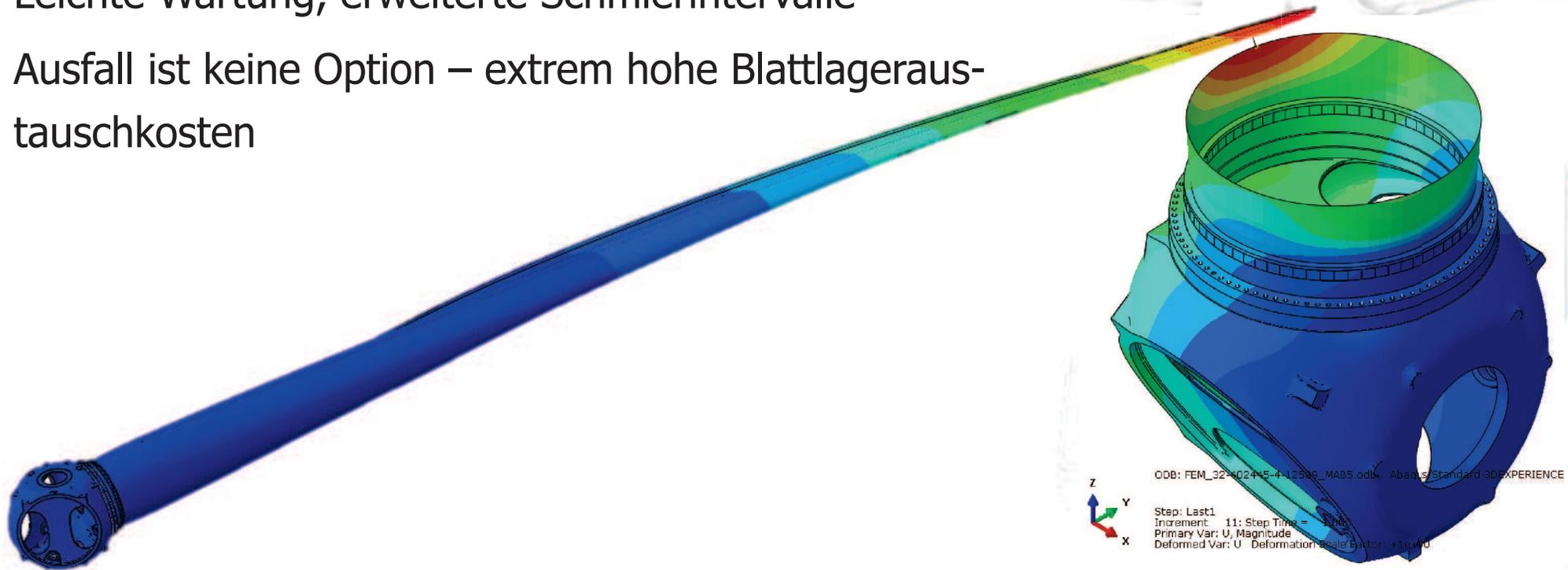
27. WINDENERGIETAGE
DER RUMMEL GEHT WEITER
06. BIS 08. NOVEMBER 2018 IN LINSTOW



Stand 60

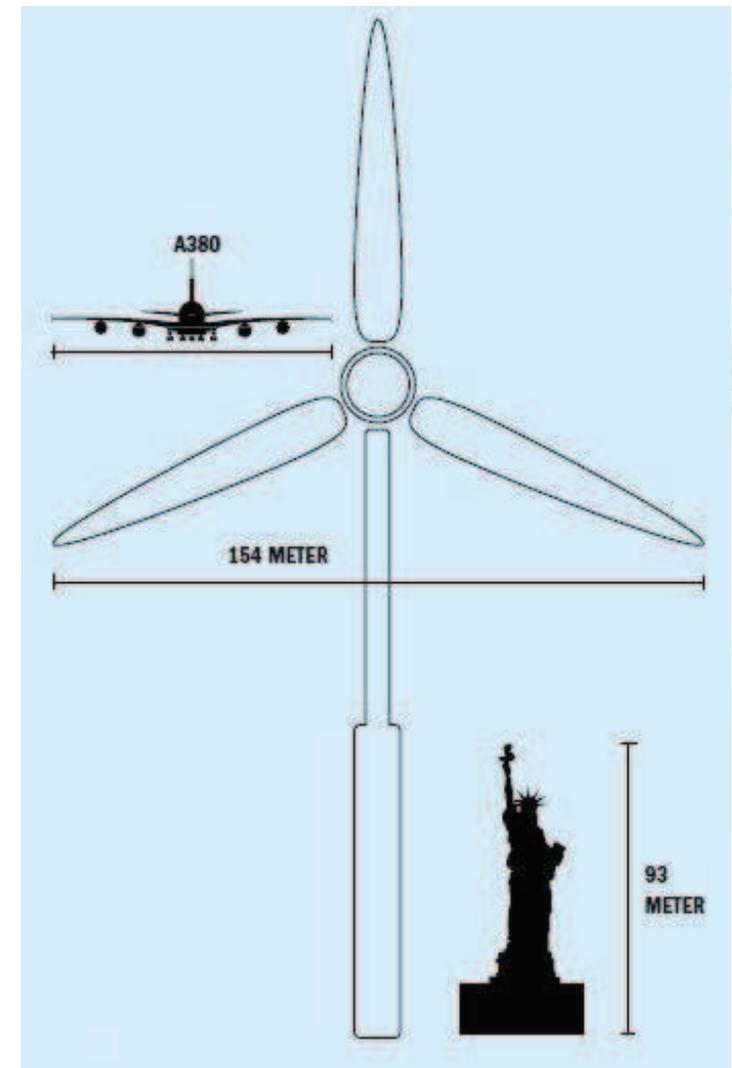
Was erwartet man heute von einem Blattlager?

- Sicherheitskritische Komponente aber Preis-/Leistungsverhältnis zunehmend entscheidend
- Durchmesser der Blattwurzel < 3 m (4 MW-Klasse)
- 24 h Dauerbetrieb über 25 Jahre
- Leichte Wartung, erweiterte Schmierintervalle
- Ausfall ist keine Option – extrem hohe Blattlageraustauschkosten



Welche Anforderungen stellt der Markt?

- Auktionen um die LCOE zu senken
 - treiben Rotordurchmesser und Nabenhöhe
- Höhere Lasten und höhere Lastunterschiede
 - treiben Lagertragfähigkeit
- Experten erwarten
 - Rotoren von 175+ m Onshore
 - Rotoren bis zu 250 m Offshore



Vermessung des Windfeldes

- Hinsichtlich:
 - Windgeschwindigkeit und –richtung
 - Horizontale und vertikale Scherwinde
 - Windverdrehung und Turbulenzen

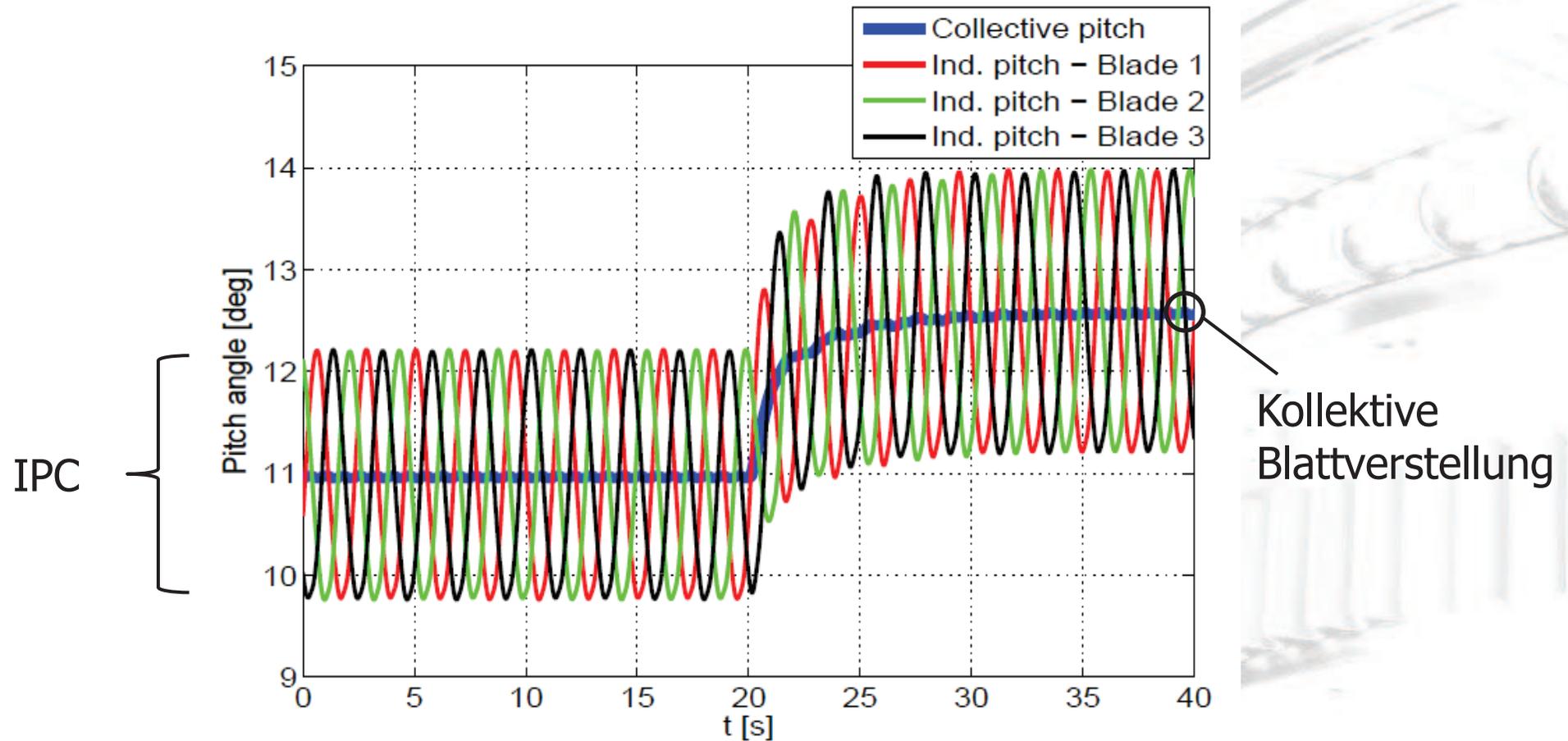
- Messung der Blattdurchbiegung und Torsion mittels neuartiger Sensoren

- Ziel:
 - Modellierung des Windfeldes in Rotor-ebene in Echtzeit
 - Lastbasierende Blattverstellung
 - Lastreduktion durch individuelle Blattverstellung (IPC)



Unterschiede im Betriebsmodus

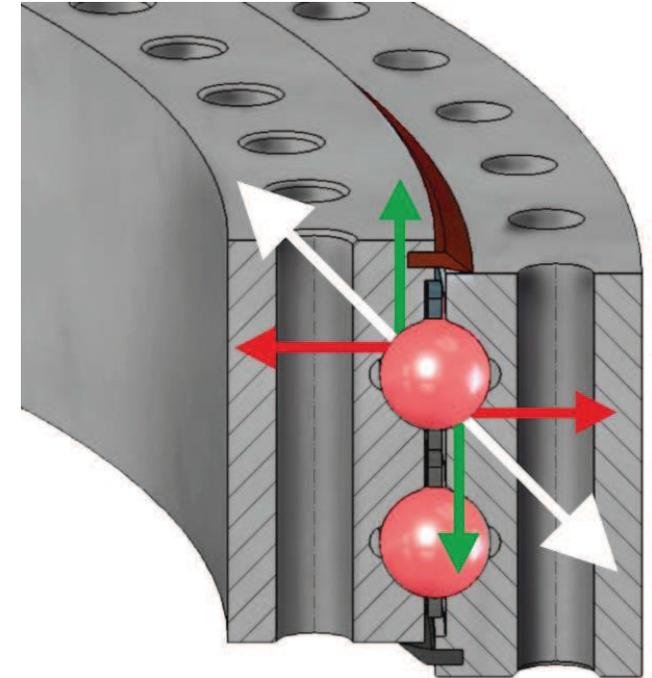
Kollektive Blattverstellung vs. IPC (individuelle Blattverstellung)



IPC treibt die Lagerlebensdauer

Probleme von zweireihigen 4-Punkt Blattlagern

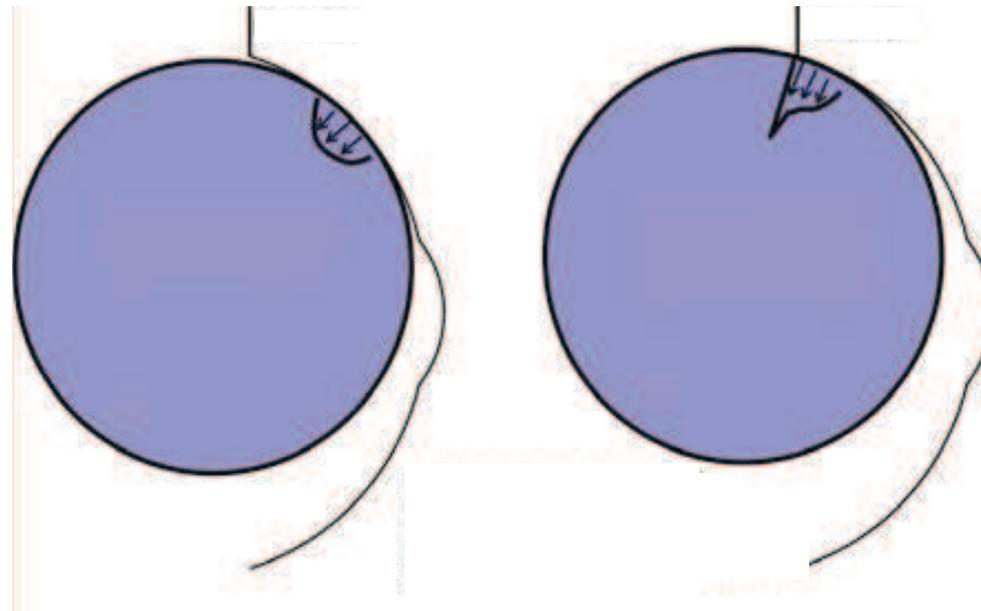
- 45° Kontaktwinkel führt zu internen Radialkräften
- Radialkräfte führen zur Ringaufweitung
- Mögliche Konsequenzen:
 - Kantenlauf der Kugeln in Laufbahn
 - Ringspannung überschreitet akzeptables Niveau
 - Höhere Anfälligkeit gegenüber Spannungsrisskorrosion
 - Fettleckage auf Grund von Ringaufweitung



- Fazit:**
- ➔ Häufige Pitch-Fehler, Produktionsverlust
 - ➔ Risiko frühzeitig ausfallender Blattlager, extrem hohe Austauschkosten

Risiko: Kantenlauf und Kantenbruch

- Kugelkontaktpunkt bewegt sich hin zur Laufbahnkante
- Abschneiden der Hertz'schen Druckellipse, lokale Überlast, Risiko des Kantenbruchs



Lösung: 3-reihige Rollenlager



T-SOLID 4IPC



Merkmale:

- 3 Ringe / 3 Laufbahnen
- Geteilter Innen- oder Außenring
- Zwei axiale Laufbahnen, 90° Kontaktwinkel der Rollen, nahezu belastungsunabhängig
- Eine radiale Laufbahn, 0° Kontaktwinkel der Rollen
- Rollenseparation in Axialbahnen durch Distanzstücke, kein Käfig zwingend
- Füllstopfen entfällt vollständig
- Für elektrische und hydraulische Pitch-Systeme gleichermaßen geeignet



Vierpunktlager vs. 3-reihiges Rollenlager



- 2 Kugellaufbahnen
- Punktberührung im Wälzkontakt
- > 99% der Feldpopulation



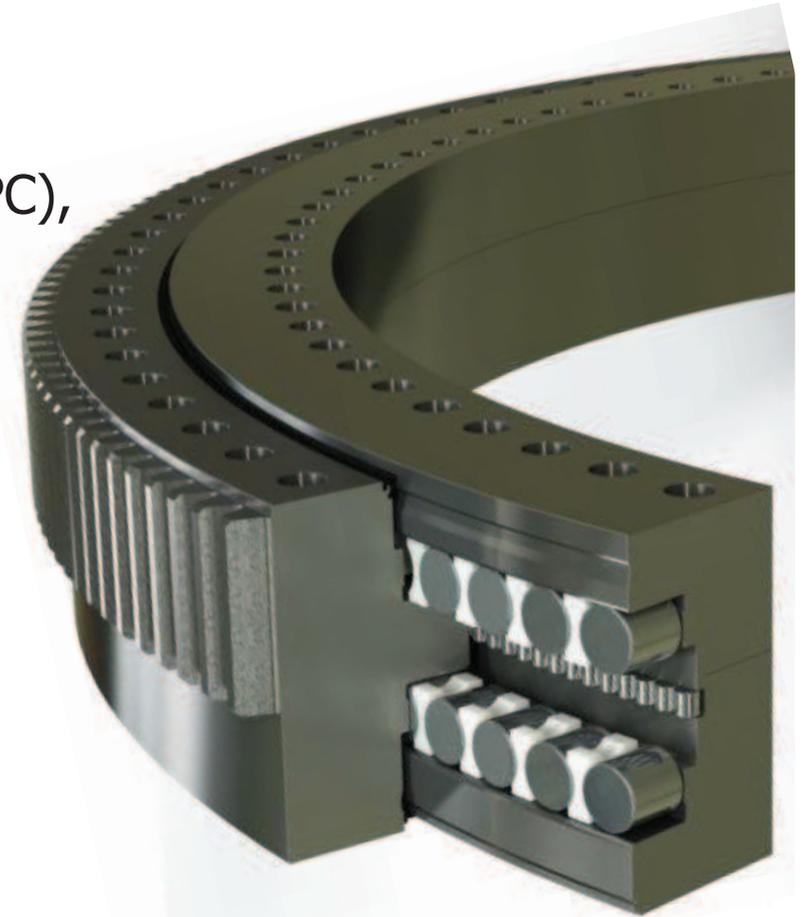
- 3 Rollenlaufbahnen
- Linienberührung im Wälzkontakt
- < 1 % der Feldpopulation



T-SOLID 4IPC

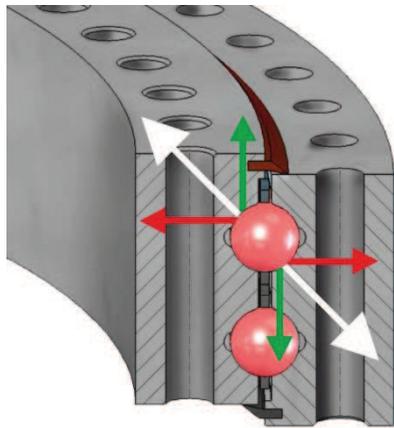
Blattlager der nächsten Generation

- Bewährte Bauform
- Unabdingbar bei individueller Blattverstellung (IPC), was wiederum essentiell wird für zukünftige Ultraschwachwindturbinen und große Offshore-Rotoren
- Setzt ausreichend steife Struktur der Blattwurzel und Nabe voraus
- Häufiges Verstellen unabdingbar (zum Erhalt des Schmierfilmes)
- Vorteil: Strukturlasten können um bis zu 30% gesenkt werden – höhere Blattlagerkosten zahlen sich aus!

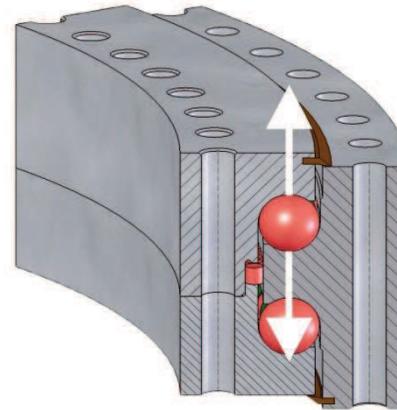


Die T-Solid Familie

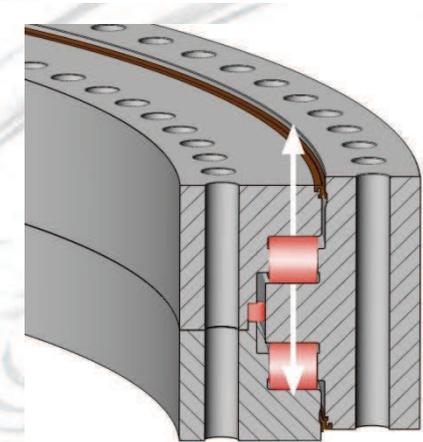
2-reihige Kugeldrehverbindung



- Vierpunktlager
- 45° Kontaktwinkel



- Wechsellager
- 90° / 0° Kontaktwinkel



- Wechsellager
- 90° / 0° Kontaktwinkel



- Zwei axiale Kugellaufbahnen, eine radiale Rollenlaufbahn
- Sehr gut geeignet
 - für große Rotoren (Schwachwind / Onshore und Offshore)
 - bei ausreichend großer Blattwurzel
 - bei kollektiver Blattverstellung



T-SOLID AUSTAUSCHSATZ

➤ Retrofit Kit für frühzeitig ausfallende 4-Punkt-Blattlager

➤ Paradigmenwechsel:

Wenn man die schädlichen Verformungen nicht vermeiden kann, muss ein Blattlager gewählt werden, das diese einfach mitgeht!

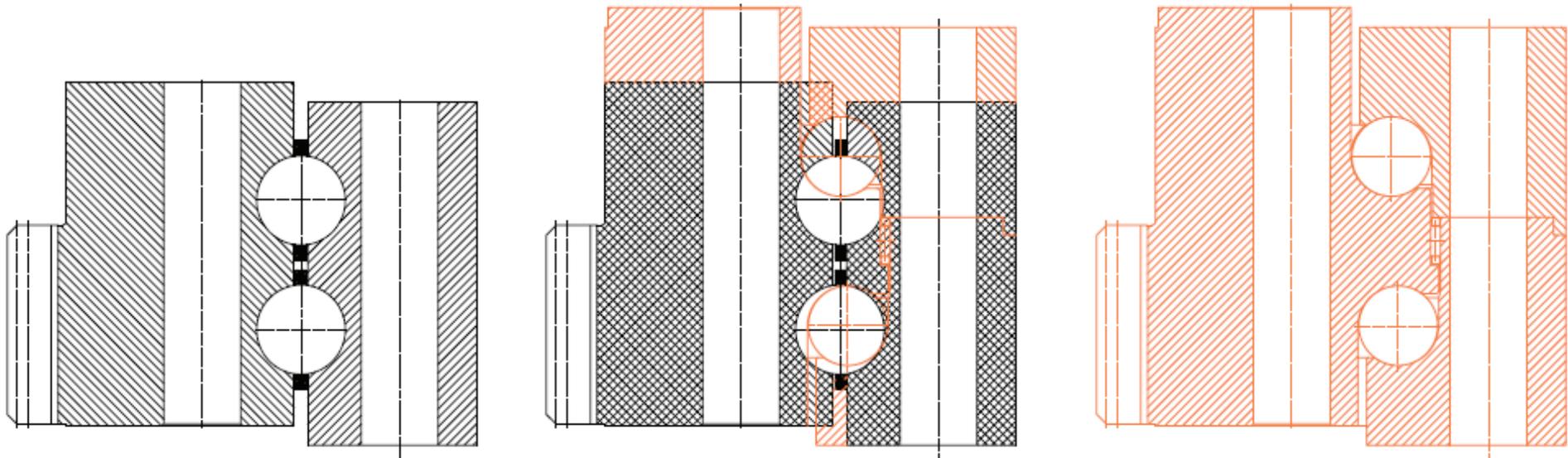
➤ Herstellerunabhängige Lösung für alle Windkraftanlagen und Blattlager





T-SOLID AUSTAUSCHSATZ

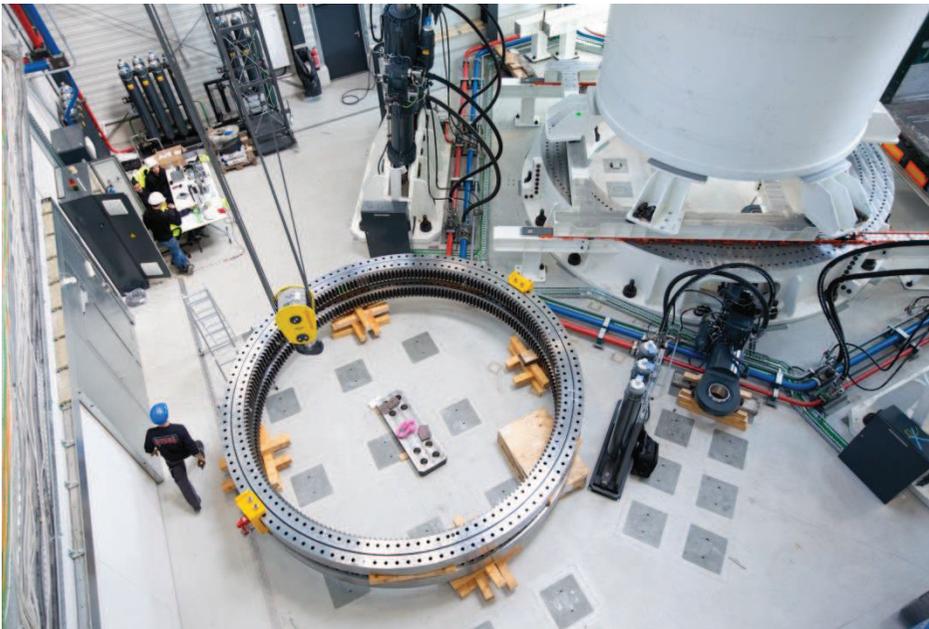
Vergleich im Bauvolumen



- Gleicher Blatt- und Nabenanschluss
- Etwas höhere Ringe (unkritisch)

Blattlagerprüfung in neuer Dimension

- Beschleunigter Blattlagertest (highly accelerated pitch bearing test – HAPT)
→ 20 Jahre in 6 Monaten
- IMO ist Industriepartner des FhG IWES und der Uni Hannover
- Teststand in finaler Bauphase in Hamburg-Bergedorf
- Geeignet für Blattlager bis 10 MW und Lagerdurchmesser bis 6.5 m



Alternative Verwendung von 3-reihigen Rollenlagern

- Beispiel: 4 MW Azimutlager
- Erlaubt einen kleineren Turmkopfdurchmesser
- Verwendet bei hohem Lastabtrag und begrenztem Bauvolumen / Durchmesser



Alternative Verwendung von 3-reihigen Rollenlagern

- Gezeitenkraftwerk 2 x 600 kW
- Verwendet für die Verstellung der 14 m langen Rotorblätter
- Hielt problemlos 5 Jahre dem Unterwasserbetrieb stand bis zum vorab geplanten Rückbau (Demonstrationsanlage)



Danke für Ihre Aufmerksamkeit!

Fragen? Stand 60!

Kontakt:

werner.schroepfel@imo.de

Tel. +49 9193 6395 1481

IMO GmbH & Co. KG

Imostr. 1

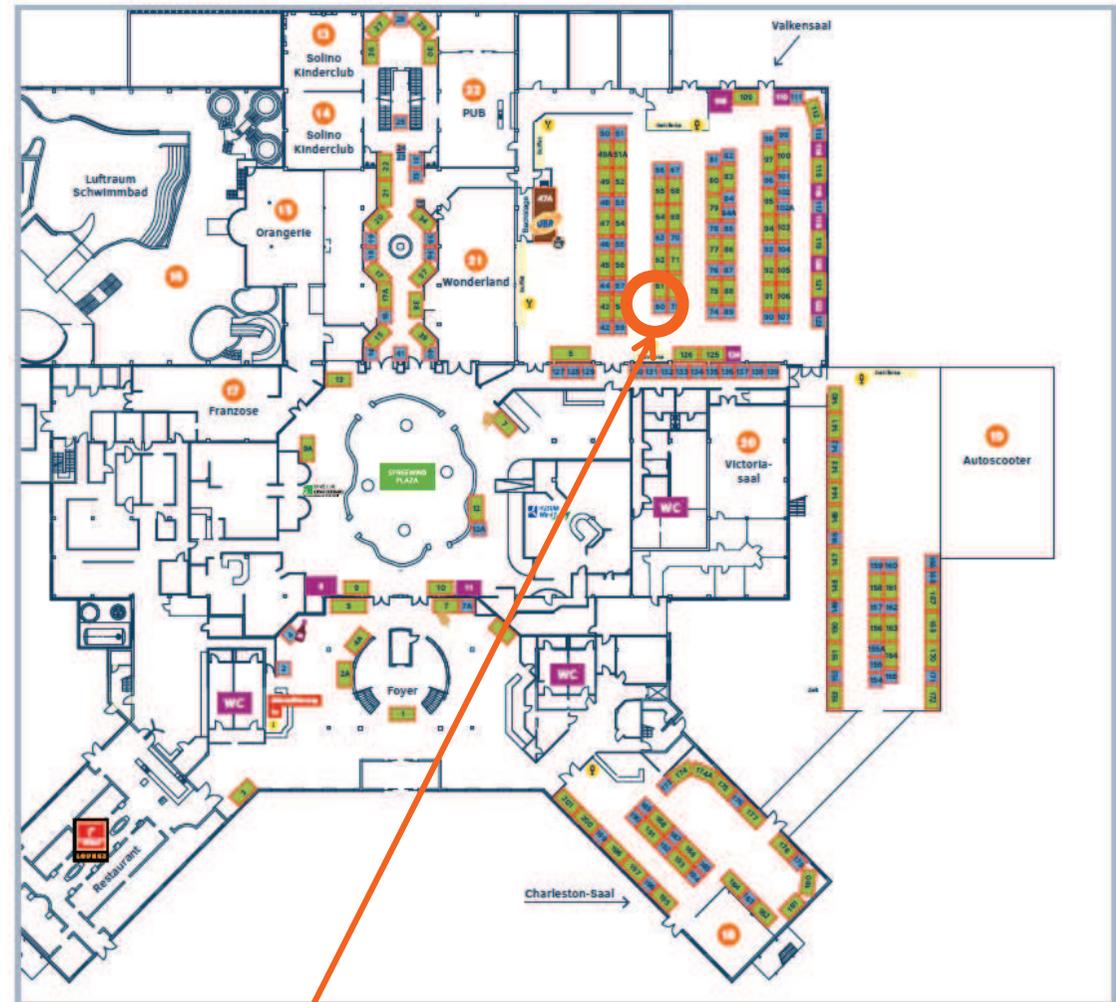
91350 Gremsdorf

Telefon: +49 9193 6395-3126

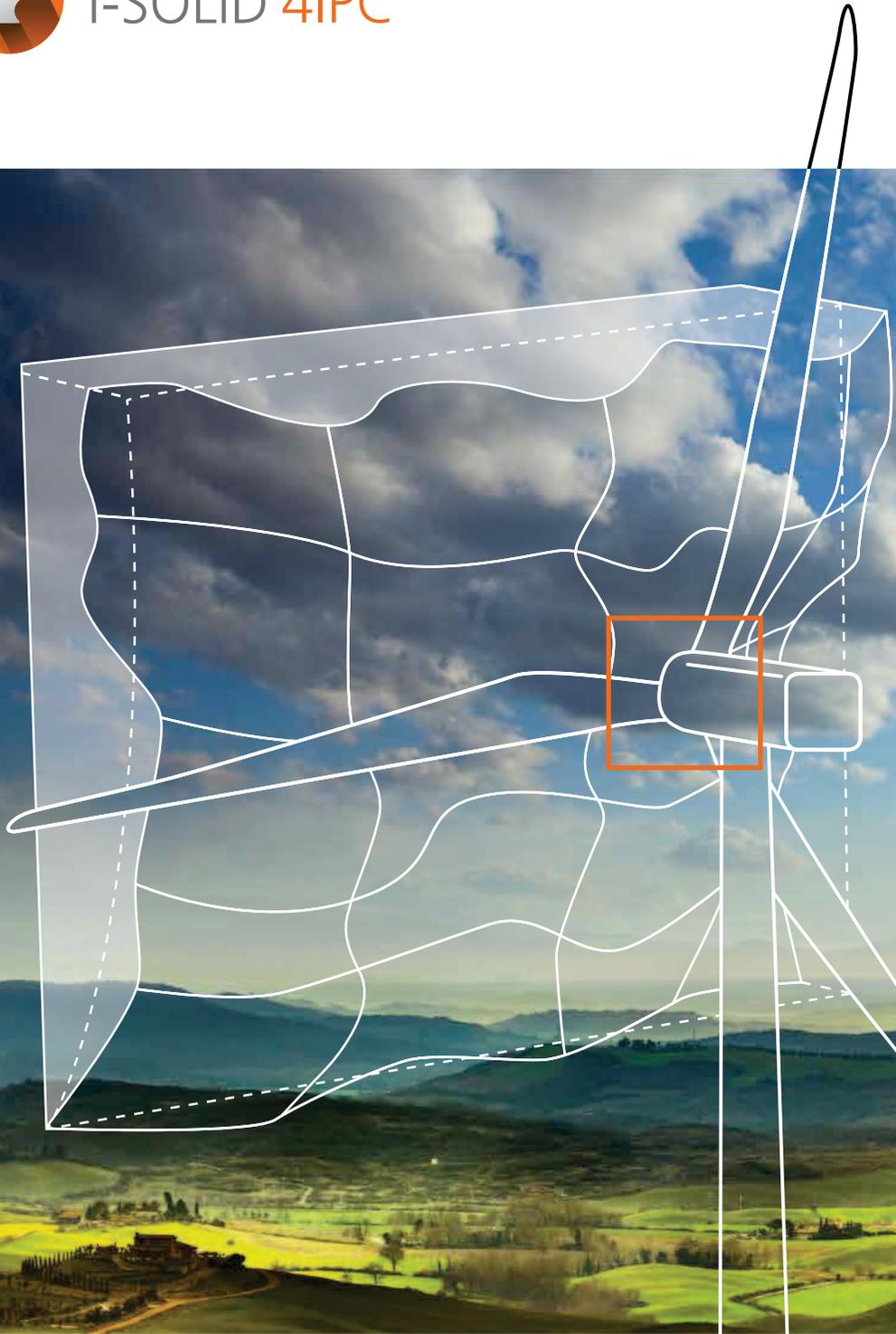
Telefax: +49 9193 6395-1140

E-Mail: wind@imo.de

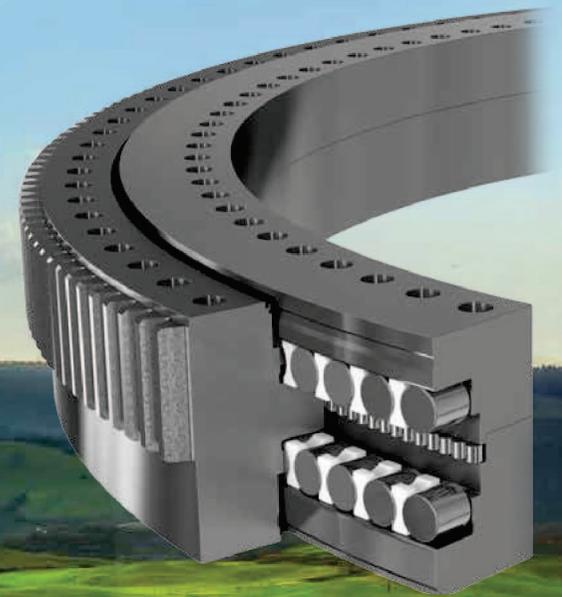
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IMO, Stand 60



NEXT
LEVEL
PITCH
BEARING



The Solution

T-Solid 4IPC, a 3-row roller bearing especially designed for

- individual pitch control (IPC)
- large rotors of 3 to 4 MW low wind-site turbines
- higher rated offshore turbines from 6 to 10 MW
- high turbulence environments
- high cyclic loads and load fluctuations



Characteristics

- three-ring-design: T-shaped solid blade mounted ring, split hub mounted ring
- two axial raceways, 90 deg roller contact angle
- single row radial raceway, 0 deg roller contact angle
- roller separation by spacers in axial raceways

What's the advantage potential?

Unsurpassed operational life

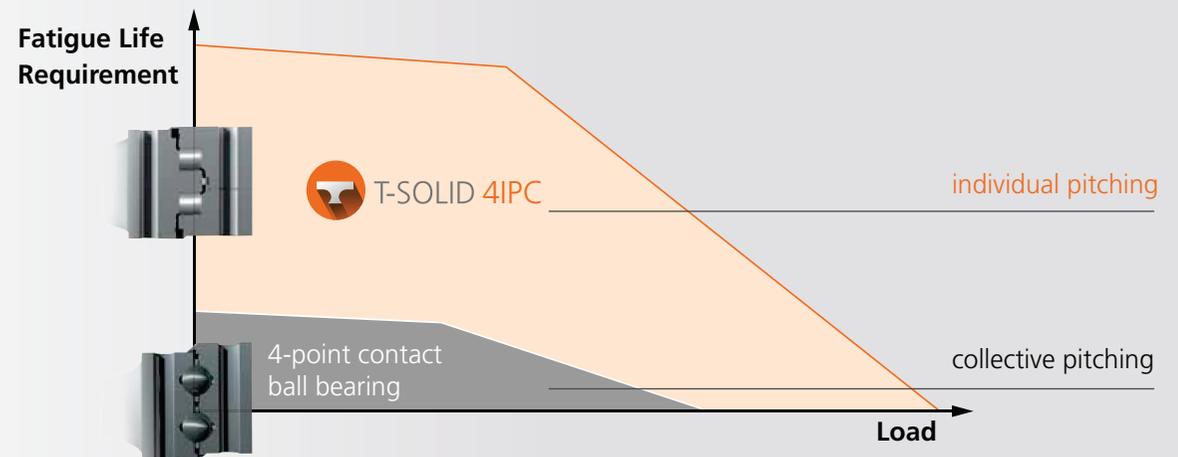
- fulfills IPC bearing life requirements
- satisfies extended service life of 25+ years

90 deg contact angle instead of 45 deg

- no raceway edge loading
- less deformation under load, less leakage
- smooth running, no peaks
- less drive torque under load

Fatigue Life Requirement

Individual pitch control (IPC) requires a much higher bearing fatigue life.





The Situation

Today's onshore low and medium-wind turbines often operate in high-turbulence environments and require large rotors and high towers for maximizing energy capture for improved yield. Whereas the offshore leveled cost of energy (LCOE) reduction trend is higher ratings and matching rotor size.

Long blades face high cyclic loads and load fluctuations, answered by individual pitch control (IPC) as a key load reducing strategy. Cyclic-IPC technology is now being gradually succeeded by load-dependent real-time IPC-technology. 4-point contact ball pitch bearings are reaching their limits, especially in fatigue life.

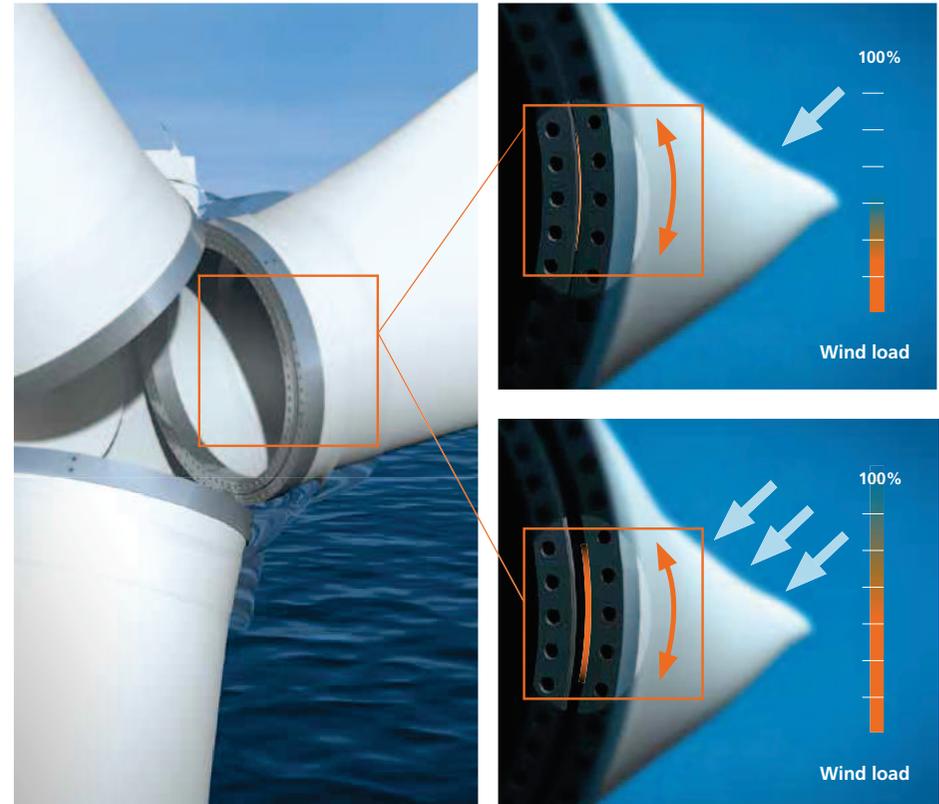
The Hazards

- high cyclic ring stresses
- heavy structural deformations
- fatigue life issues
- grease leakage due to ring separation
- raceway edge loading

The Challenges

Aerodynamic forces act upon the blade and result in high moment loads on the pitch bearing causing high stresses and heavy deformations. Turbine service life extension to 25+ years combined with considerably increased pitching activity

for structural load reduction requires a new pitch bearing design facilitating a 4-8 times longer life than the widely used 2-row 4-point contact ball bearing used for decades.



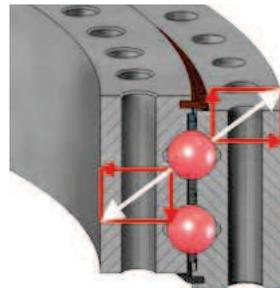
What's new?

Loads transmitted in a different way

4-point contact ball bearing

- all loads resolve into axial and radial components
- radial component causes bearing gap widening
- ball contact angle moves towards raceway edge

Load transmission



Contact angle variation

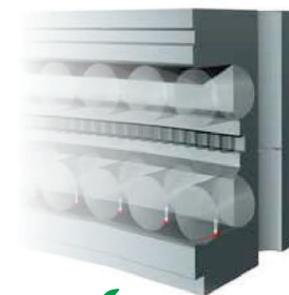
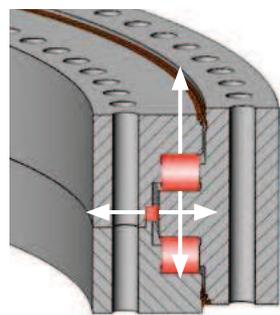


Change of contact angle under load

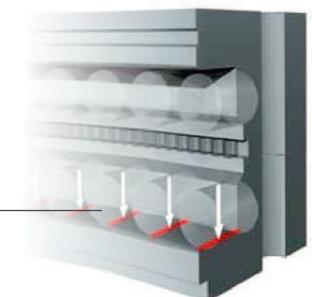


T-SOLID 4IPC

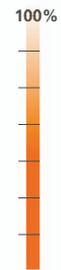
- axial load components carried by axial raceways
- radial loads carried by radial raceways
- insignificant bearing gap widening
- constant roller contact angle
- significantly reduced ring stress



No change of contact angle under load

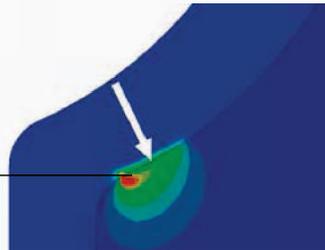


Edge loading



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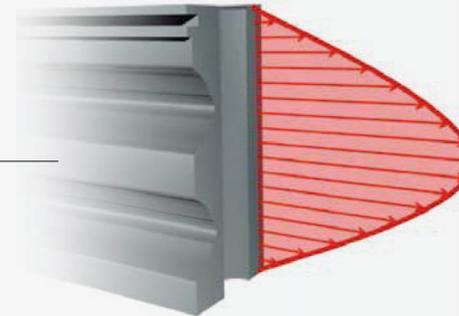
Risk of raceway edge loading



Wind load

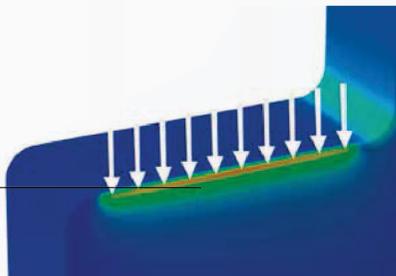
Ring stress

High ring stress due to 45 deg contact angle



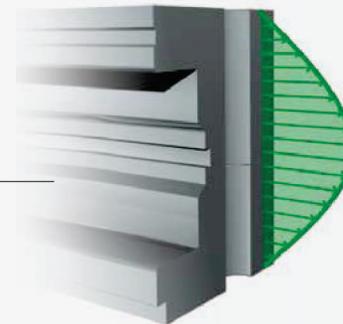
✓

No risk of raceway edge loading



Wind load

Low ring stress due to 90 deg contact angle



The Pros

Edge loading
Eliminated

Ring separation
Factor 4-8 reduced

Ring stress
Factor 2-3 reduced

Lifetime
Significantly extended

Fatigue Limit
Factor 10 extended



T-Solid 4IPC unfolds new perspectives for reduced cost of ownership, ensuring your return on investment!

Superior turbine design-to-cost ratio

- enables individual pitch to reduce structural load
- less load, less tower top mass, slimmer tower
- increased Annual Electricity Production (AEP), better return (ROI)
- lower Levelized Cost of Energy (LCOE)

Risk reduction, reliability improvement

- less pitch errors, increased turbine availability
- proven and bankable design concept
- lower replacement risk in field
- no grease leakage, less environmental concern



IMO follows the technical guidelines set by leading certifying authorities when calculating the slewing ring performance and life capabilities.

IMO co-operates with Fraunhofer IWES and Leibniz Universität Hannover in the joint HAPT project (Highly Accelerated Pitch Bearing Test), where a test bench will cover the current and next generation offshore pitch bearings up to 10MW.

IMO GmbH & Co. KG
 Imostrasse 1
 91350 Gremsdorf
 Germany

Tel. +49 9193 6395-0
 Fax +49 9193 6395-3140
 wind@imo.de
 www.imo.de



T-Solid – Smart retrofit kit for prematurely failing pitch bearings



Field issues

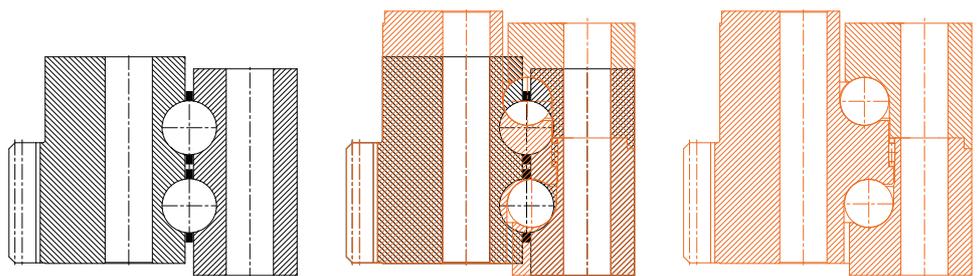
- Several 4-point contact pitch bearings fail prematurely and need to be replaced
- Neither blade root nor hub can be fundamentally reinforced on site
- Excessive deformations result in higher torque which may cause frequent pitch errors
- Often a replacement only temporarily fixes the issue until another costly pitch bearing replacement is required

Change in paradigm

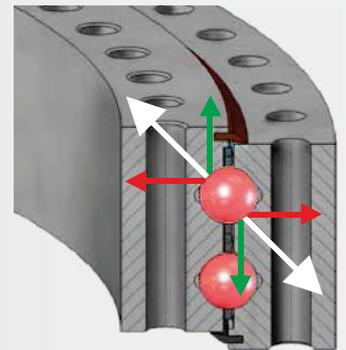
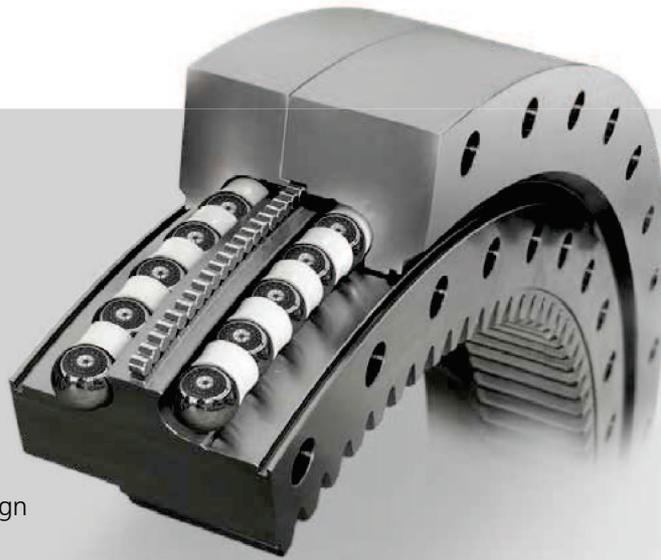
If you cannot avoid the detrimental deformation effects, choose a bearing design which can simply withstand it!

Solution – IMO's T-Solid retrofit kit

- Safe operation even under heavy deformations thanks to its advanced 3-rings/3-raceways design
- No ring expansion due to no additional radial forces from load transmission
- No edge loading, no raceway spalling, no cage overload, no leakage issues
- Same hub and blade bolt circle diameters, same gears! Exact replacement, only bearing height increases slightly
- Higher efficiency due to reduced friction torque
- Manufacturer independent design, suitable for all fielded turbines and pitch bearings – can be tailored to your individual requirements
- Designed by industry experts
- Field proven in 2-3 MW wind turbines



T-Solid (in orange color) compared with 4-point contact pitch bearing to be replaced – same bolt pattern, same gearing! Longer bolts are required due to slightly increased bearing height.



Specifications

- 3-rings/3-raceways design
- Inner or outer ring split
- Double row axial raceways
- 90 deg ball contact angle
- Single row radial raceway
- 0 deg roller contact angle
- Ball separation by spacers
- No filling plug required
- For electric & hydraulic pitch

Retrofit kit includes pitch bearings, new bolts, nuts & washers

Your advantages

- Easy retrofit, same form, fit & function
- 20 year service life
- Improves your AEP (annual electricity production)
- Ensures your ROI (return on investment)

In 4-point contact pitch bearings the forces always result in radial loads which periodically widen the outer bearing rings.

By contrast, in IMO's T-Solid bearings the dominating axial forces will be directly passed through.

