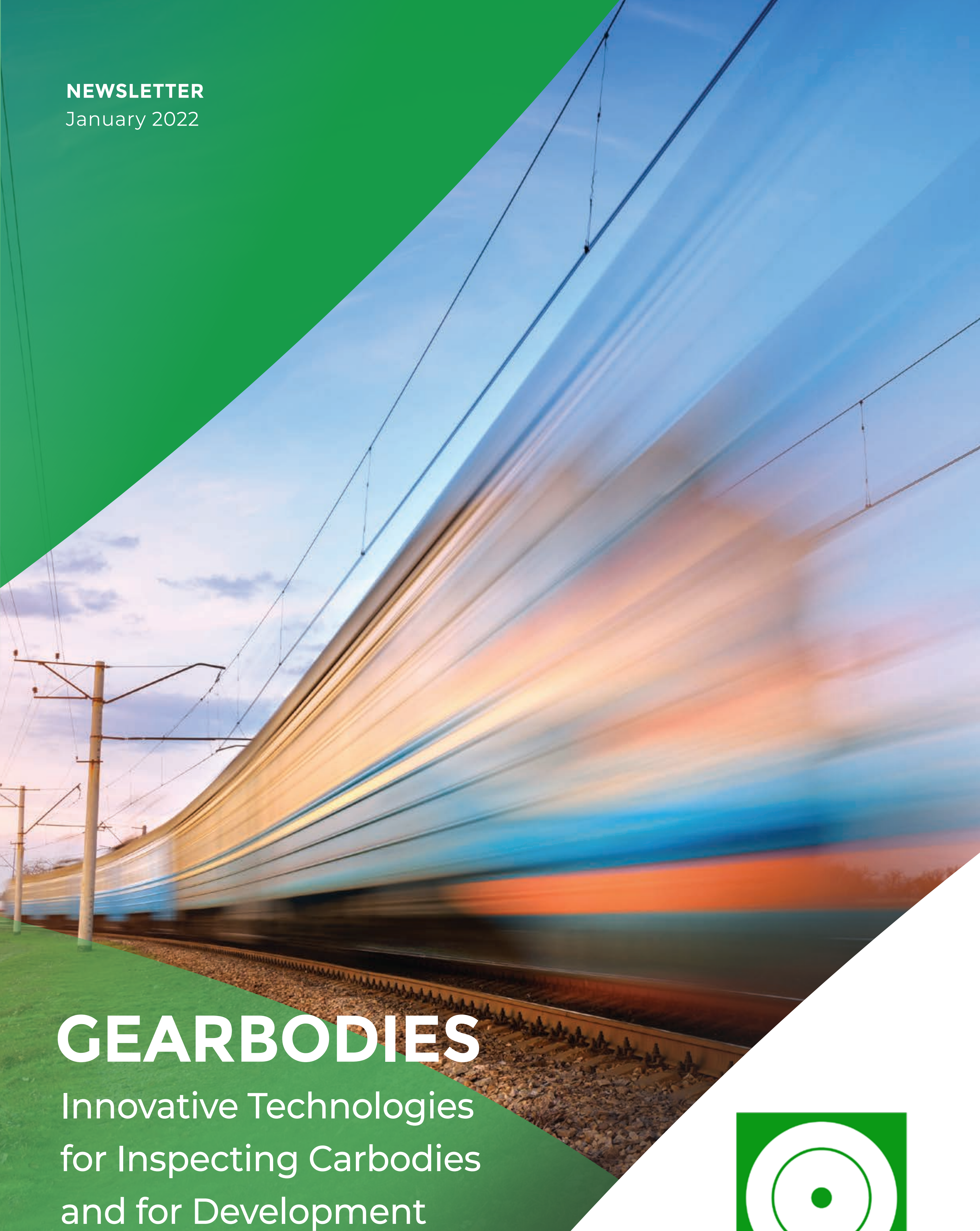
NEWSLETTER
January 2022



GEARBODIES

Innovative Technologies for Inspecting Carbodies and for Development of Running Gear

GEARBODIES

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Foreword/ Introduction

In this 1st newsletter of the **GEARBODIES** project (Innovative Technologies for Inspecting Carbodies and for Development of Running Gear), you will learn about the current developments, as the project has reached its halfway point. Through the various achievements that are being summarised, you should also get an idea of what's to come going forward, until the project concludes at the end of December 2022.

To find out more about GEARBODIES and its objectives, to access the public deliverables and to get a closer look at the project partners, please visit our website at:
www.gearbodies.eu

Enjoy the read!

Project scope & structure

The GEARBODIES project works towards the development of cost-efficient and reliable trains by contributing with specific innovations to Technology Demonstrators (TD) of Innovation Programme 1 (IP1) within Shift2Rail, through two dedicated work streams:

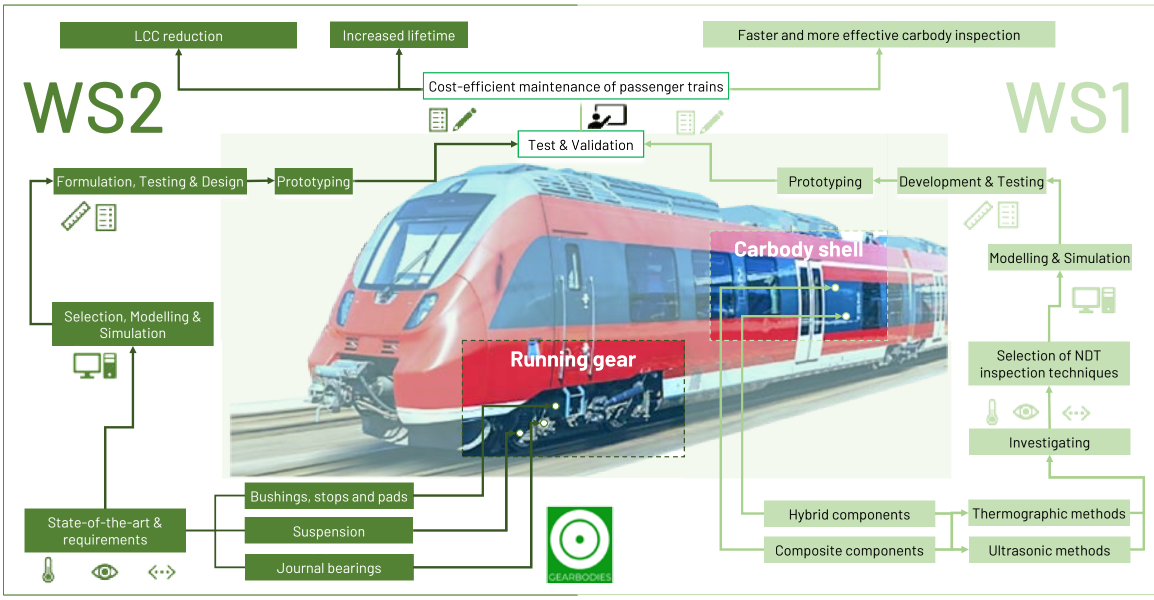
- Work Stream 1 (WS1): Inspection methods for innovative new carbodies that use lightweight composite materials (TD1.3), which aims to develop effective, affordable and automated solutions for non-destructive inspection of such vehicles;
- Work Stream 2 (WS2): Innovative approaches for developing running gear components (TD1.4), which aims to employ innovative approaches, tools and methods for developing novel concept designs of running gear components with extended lifetime, and low LCC, whilst maintaining or reducing current levels of reliability, noise emissions, and track damage.

In addition, the GEARBODIES consortium will liaise and work together with Shift2Rail members to allow for correlating and/or implementing their innovations into the final technological demonstrators (TDs) namely: TD1.3 “Carbody Shell Demonstrator” for WS1 and TD 1.4 “Running Gear Demonstrator” for WS2, contributing thus to the overall Shift2Rail IP1 strategy.

The two Work Streams of GEARBODIES will actively contribute to improving the efficiency, safety and competitiveness of the European railway sector by supporting the implementation and exploitation of innovative materials and practices, with profound impacts on the cost-efficiency and reliability of the sector, as well as on its energy consumption and infrastructure maintenance. Inspection time will be significantly reduced, while the use of new materials and systems will enable an increase in the lifetime of components and lower maintenance costs.

The common element of WS1 and WS2 is the contribution towards the improvement of rolling stock maintenance processes through 1) the use of highly automated non-destructive testing (NDT) techniques for the inspection of composite carbody shells (WS1), and 2) the development of running gear components with enhanced performance (WS2).

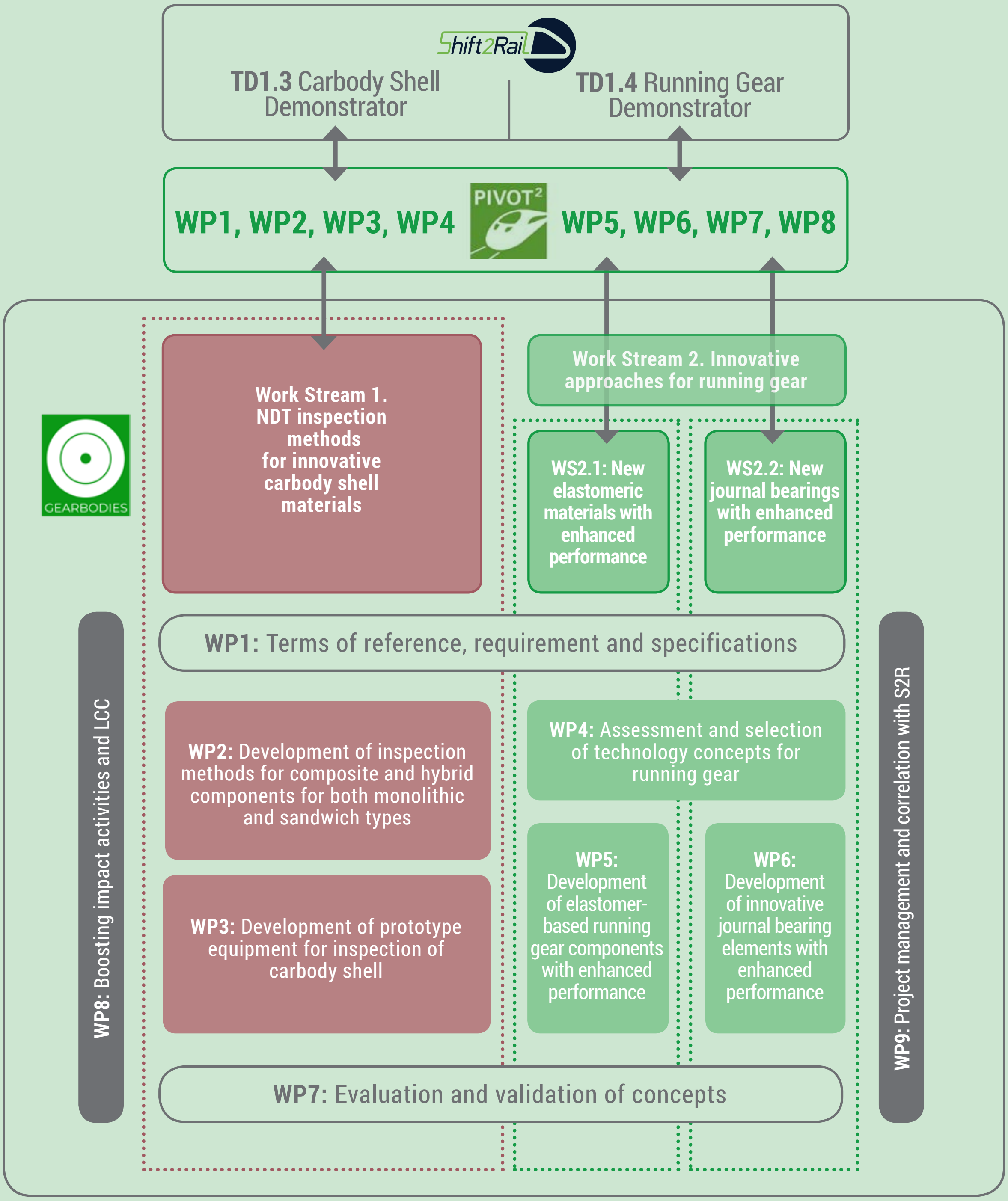
FIGURE 1
Overview of GEARBODIES concept



GEARBODIES has been structured in 3 functional Work Streams (WS1, WS2.1 and WS2.2). WS1 focuses on the development of an automated platform prototype for inspecting composite carbody shells utilising NDT techniques such as thermography and ultrasonic testing. To facilitate the work, WS2 has been divided into 2 different Work Streams, each one centred on specific elements of the running gear. WS2.1 works on innovations related to elastomer-based components, while WS2.2 focuses on innovations for journal bearings. The three WSs will start and finish with two cross-cutting WPs (WP1 and WP7), which will contribute to harmonising the results and providing coherence to the project development. Finally, two transversal WPs (WP8 and WP9) complete the structure of the project. WP8 comprises a set of activities to increase the impact of the project and to perform the LCC assessment. WP9 provides the project management and ensures the relationship with S2R.

The figure below illustrates how the project is organised:

FIGURE 2
GEARBODIES project structure



WS1 NDT inspection methods for innovative carbody shell materials

The project started with an investigation of technologies and procedures, both existing ones, which are currently employed or under development by industry (TRL 6-8), and emerging concepts that are currently investigated by research organisations and universities (TRL 2-5). The scope was to outline the foundation and terms of reference of the project in relation to methods and technologies for surface and sub-surface inspection of composite and hybrid carbodies.

This initial study of WP1 was completed in the first five months of the project and all the specific objectives have been achieved. i.e.

- Existing and emerging technologies and technical solutions have been identified, reviewed and assessed, with focus on the most relevant use cases, which have been identified and discussed with the complementary project for Shift2Rail members, PIVOT2. This enabled to define the focus of further work, on active thermography and ultrasonic inspection techniques. The potential inspection methods will be first investigated through modelling and simulation, tested in lab trials, and finally get validated further through an experimental inspection rig, on a prototype composite carbody that will be manufactured by the PIVOT2 project.
- High-level requirements for the selected inspection technologies that are relevant to identified key use cases have been identified and assessed;
- Technical high-level specifications for the innovative technologies and technical solutions that are envisaged by WS1 have been defined for being followed up by further technical developments in the project.

Under WP2, the GEARBODIES project aims to investigate in a theoretical level, as well as lab environment, the application of Infrared Thermography (IRT) and Ultrasonic Testing (UT) as suitable NDT methods for inspecting composite rail carbody shells during their maintenance phase in order to detect damage and defects on the side walls of the structure. WP2 is structured in three main tasks as illustrated below:

Investigation of suitable IRT and UT technique through modelling → **Development of inspection approaches in lab environment** → **Data processing and pattern recognition software tools** →

The first part of WP2 consists of using software modelling and simulations to investigate the suitability of specific IRT and UT techniques in detecting surface and sub-surface defects on composite and hybrid components, of monolithic or sandwich nature. This research was reported in deliverable D2.1 “Modelling investigation and assessment”. D2.1 explored the use of specific inspection techniques. Specifically, flash and optical lockin thermography as well as Lamb Waves and pulse echo for ultrasonic testing respectively. These techniques were applied on a modelled monolithic carbon fibre component (20mm thickness) and a sandwich component, consisting of carbon fibre skins and PET foam core (40mm overall thickness). Defects were introduced at different locations and depths, within the modelled samples, to simulate delaminations and disbonds between the CFRP skins and the foam core material. The modelling and simulation of the NDT techniques were carried out using ThermoCalc 3D (for IRT) and Comsol as well SimNDT (for UT) respectively. The thickness of the components has proven to be challenging for every inspection method. For the monolithic CFRP component both thermography and ultrasonic techniques have proven capable of detecting deep defects. In terms of the thermography techniques on the CFRP monolithic component, the best simulation results were provided by the optical lockin technique, showing its capability of detecting all defects. For the sandwich component, Lamb waves have shown that the technique is capable of propagating through the PET foam core and potentially finding disbonds between the front and back skins and the core. However, optical lockin thermography simulations on the sandwich component, have shown that the technique is capable of only finding defects and disbonds on the front skin and heat was unable to propagate through the entire foam core. These results require to be proven in an actual lab environment which is the next step for WP2 where the aforementioned techniques will be tested using fabricated components. These lab experiments will be also accompanied by the development of software tools that will be capable of image processing and pattern recognition for both thermography and ultrasonic testing methods.

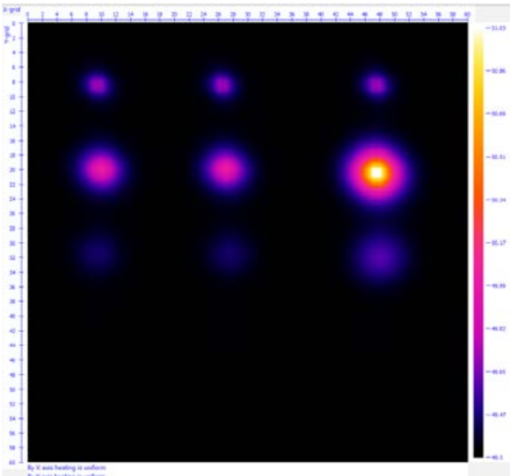


FIGURE 3

Optical lockin thermography simulation results on monolithic sample showing detection of defects

The introduction of the next generation of composite rail carbodies will require new autonomous inspection methods. Solving this challenge is part of WP3 that aims to develop autonomous modular platform that will incorporate ultrasonic and thermographic inspection equipment.

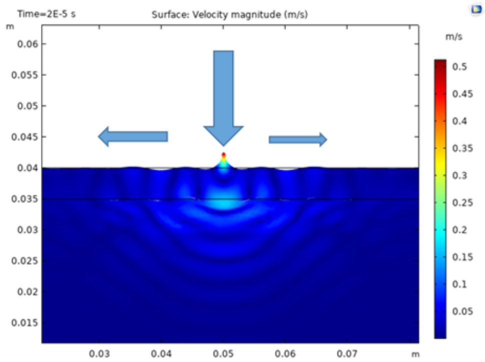


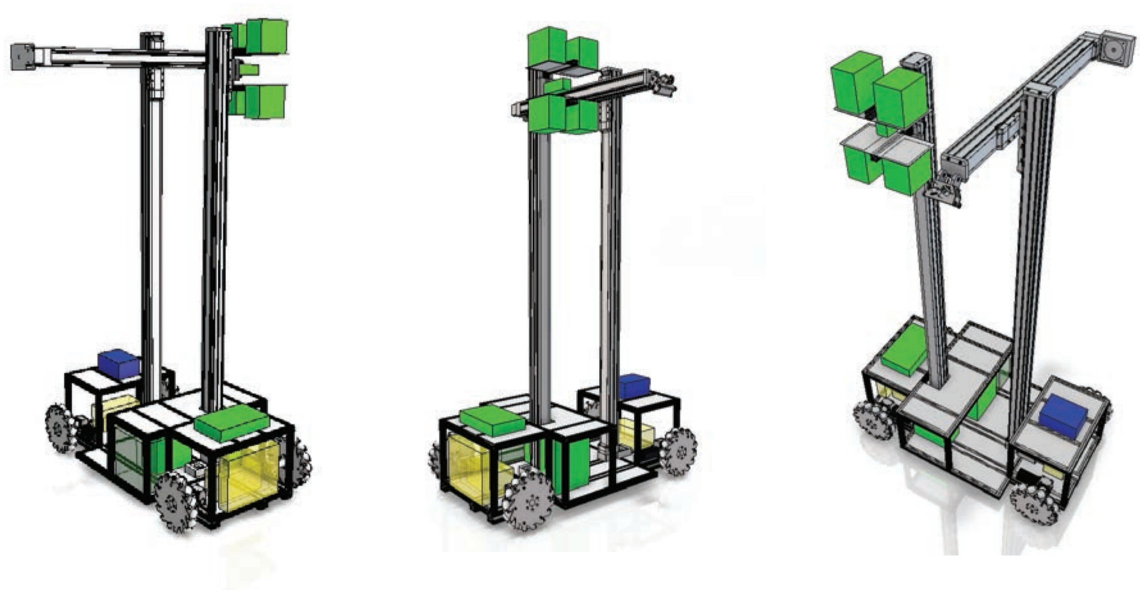
FIGURE 4

Propagation of Lamb waves at 200KHz in sandwich CFRP-PET sample

Work on the system engineering and conceptual design phases has started in September of 2021 with the GEARBODIES project currently being on the advanced design phase. During the upcoming months, the design phase will be completed with the help of robotic simulations, followed by building and testing of the mobile inspection Platform (without inspection equipment). Integration and testing of the NDT equipment in laboratory conditions will be required prior to the final test and validation of the whole GEARBODIES inspection platform on the PIVOT2 prototype rail carbody.

FIGURE 5

3D design and simulation model of the autonomous mobile inspection platform



WS2.1 New elastomeric materials with enhanced performance

The main objective of WS2 of the GEARBODIES project is to investigate the potential of novel materials and other innovative solutions for increasing the lifetime and decreasing LCC of considered components of rail vehicle running gear.

The project started with an investigation of technologies and materials, both existing ones, which are currently employed or under development by industry (TRL 6-8), and emerging concepts that are currently investigated by research organisations and universities (TRL 2-5).

In WP1, a preliminary list of elastomeric and metal-elastomeric components for running gear as well as a list of potential elastomeric materials to manufacture the components were presented. An exhaustive study of market solutions for components was carried out.

This initial study was completed and all the specific objectives have been achieved. Existing and emerging technologies, materials and technical solutions have been identified, reviewed and assessed, with focus on the most relevant use cases, which have been identified and discussed with the complementary project, PIVOT2. This background determined further focus on the most promising innovations in WS2.1 on two specific solutions: i) enhancement of material properties through the inclusion of nanotechnology; ii) development of elastomer-metal interfaces with improved properties. Further work will consider initial developments at experimental level, followed by the production of two prototype components that will be tested in laboratory according to standard specifications. In addition, high-level requirements for the candidate components and technical solutions that are relevant to identified key use cases have been identified and assessed, and technical high-level specifications have been defined for each potential case study, which would be pursued further in the project. Considering the initial selection of both components and materials, different requirements and specifications were proposed such as the main functional and operational requirements that apply in the railway field, LCC requirements, KPIs and requirements regarding compliance with standards and regulation. A selection of technical specifications for components and materials was also analysed and summarised in the WP1 report.

These candidates were further assessed and shortlisted within WP4 before being prototyped in the next steps of the project. In WP4, to define the most effective solutions for improving the features of elastomer-based components, a comparative analysis based on the Alternative Hierarchy Processing (AHP) method was carried-out. As input for the AHP experts they were asked to assess the efficiency of the alternative solutions with respect to the different criteria which are relevant for increasing the lifetime, i.e. to pairwise compare the solutions through the prepared AHP matrices. Three levels AHP hierarchy model for assessment innovation solutions and safe exploitation criteria was proposed (see in Fig.6).

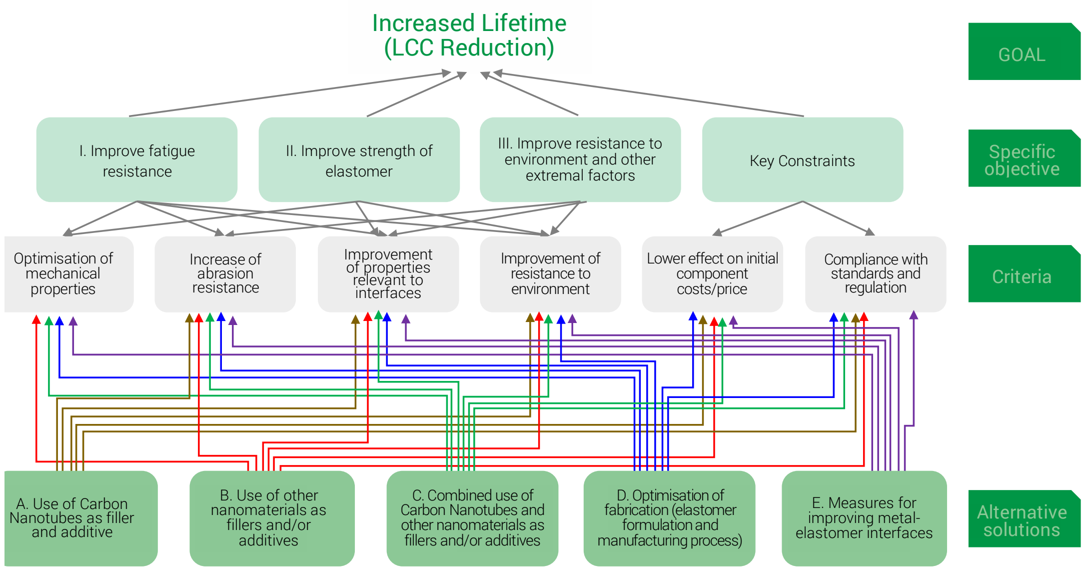


FIGURE 6

Three level hierarchy tree for selection of innovation solutions for improving of elastomer-based components

Five different types of elastomer components (adjustable torque support, emergency spring in secondary suspension, rubber interleaved (chevron type) spring (in primary suspension), bushing in longitudinal swing arm and conical rubber springs (in primary suspension)), and the analysis for each component was based on a set of 6 matrices, each of them corresponding to a specific criterion, and each matrix compares pairwise the 5 potential solutions that had been considered.

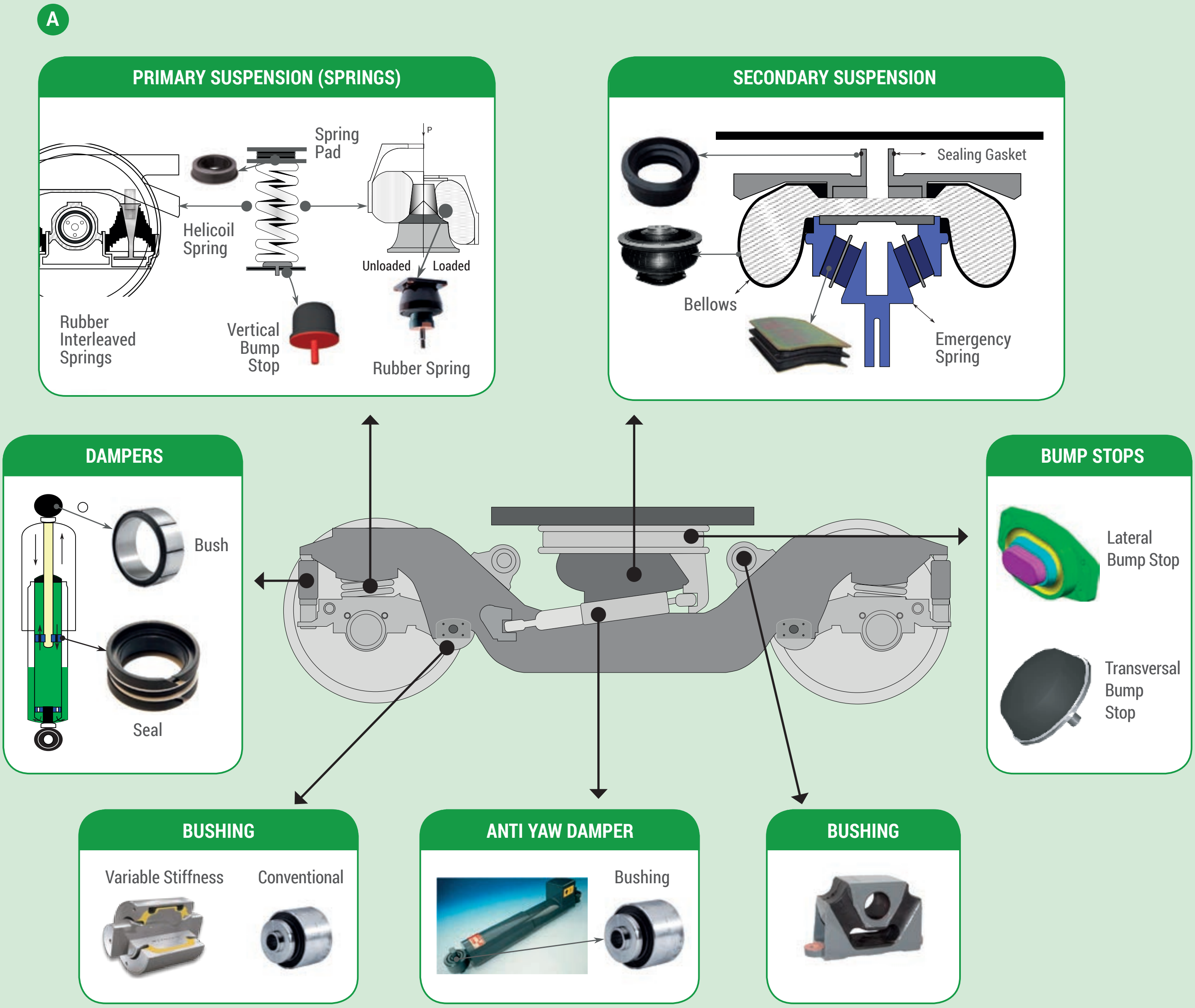
The investigated loads exerted on the considered components were determined by developing multibody simulation models of a high-speed train and comparing the loads resulting from simulations carried-out with a said model with the loads given by the standards (journal bearing EN 12082 and elastomer-based EN 13913) with a focus on the realistic dynamic behaviour.

The studies and conclusions from WP4 and WP1 will be used in WP5 in the work dedicated to developing the new elastomer material to be employed in the fabrication of improved elastomer-metal interfaces. Also, WP7 contents extracted from D4.1 will support the manufacturing of the elastomer-based components.

The plan for WP5 is to develop new elastomeric materials for components of railway gear (conical spring in primary suspension and bushing in swingarm, see Figure 7 a) based on new formulation(s) of elastomer materials, or adaptation of other eco-friendly and/or low cost high-performance elastomers, including nanotechnology solutions for enhancement of durability and lifetime, with the aim of reducing the need for replacement during the life of the vehicle. The main novelty to be developed withing this work will be the inclusion of nanotechnology. Carbon nanotubes (CNTs) have shown very important potential as filler for elastomeric composites due to their structural characteristics and their mechanical properties. Structural features and morphology of CNTs can be observed in the SEM pictures in Figure 7 b and c. Reinforcing effect of the nanotubes may be revealed by a dynamic mechanical analysis showing an increase in the storage modulus. On the other hand, tensile strength, tensile modulus and toughness increase with the filler loading while the elongation at break decreases.

New elastomer will be formulated and developed to be employed in the fabrication of improved elastomer-metal interfaces. Long term testing of elastomers and elastomer-metal interfaces will be carried out to validate the performance and durability of the elastomers and interfaces explored while feeding the information needed for upgrading the design concepts of the selected running gear components. The design cases will be adapted considering the integration of the elastomers and new interfaces as well as elastomer and interface properties, re-dimensioning etc.

A



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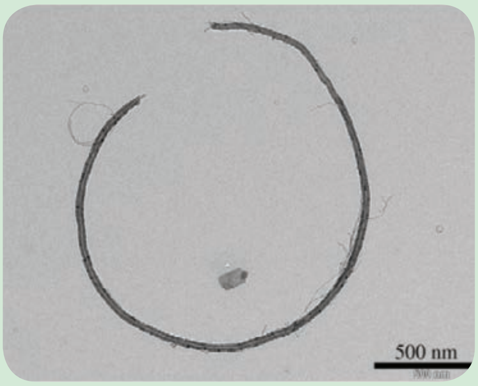

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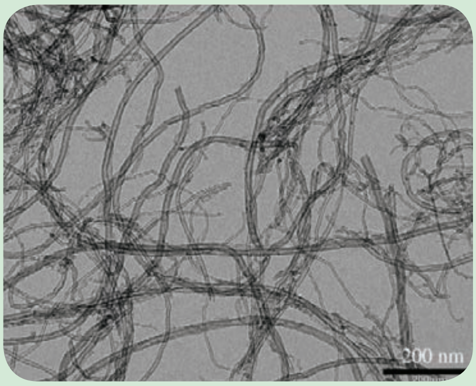


FIGURE 7

a) Elastomer-based components in running gears. (University of Newcastle). SEM pictures of an isolated carbon nanotube (b) and aggregate of several carbon nanotubes (c)*

*Bokobza, L. (2007). Multiwall carbon nanotube elastomeric composites: A review. Polymer. **https://doi.org/10.1016/j.polymer.2007.06.046**

WS2.2 New journal bearings with enhanced performance

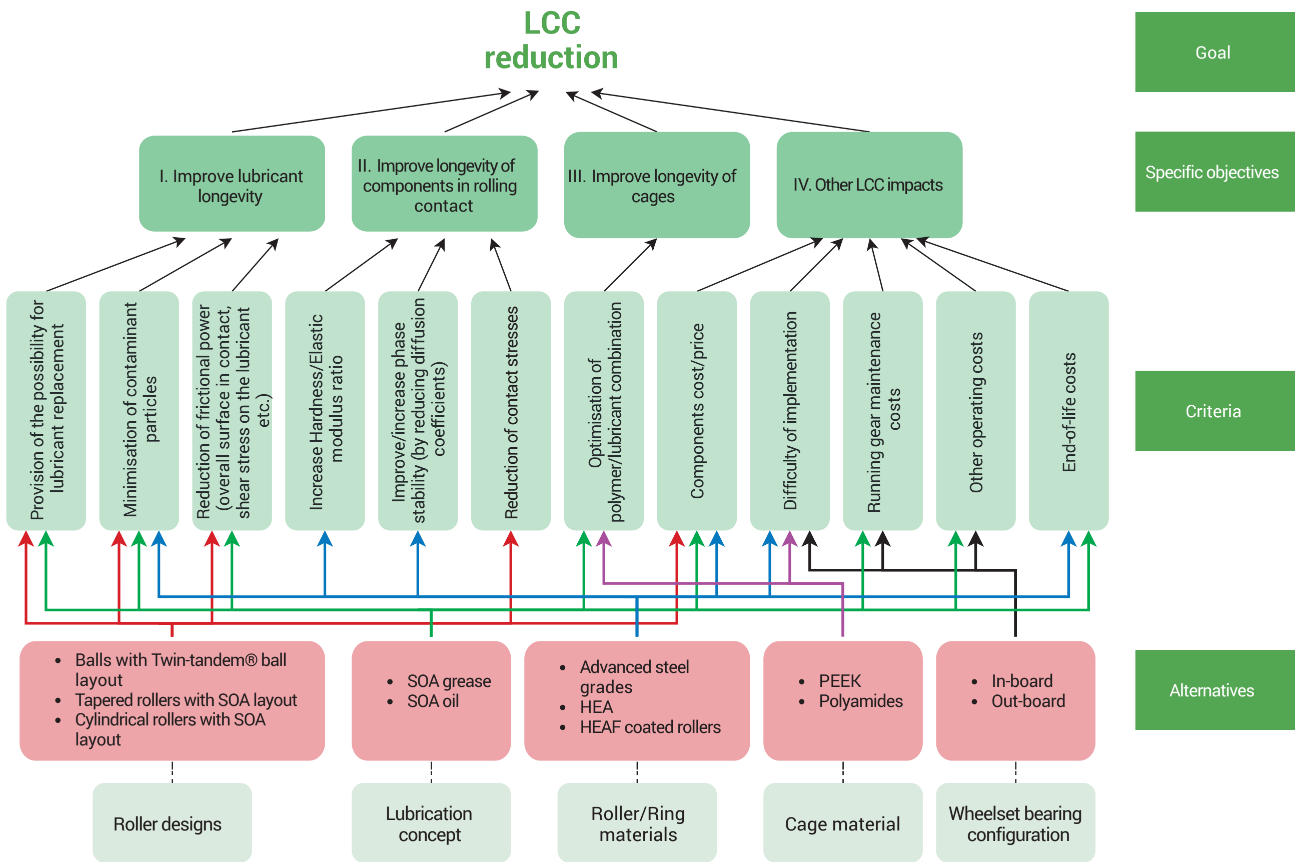
GEARBODIES WS2.2 focuses on the Life-Cycle Cost (LCC) aspects of bearing units and their lifetime, which is the main cost driver for this component. In particular, extending maintenance intervals for high-speed applications could lead to significant operator benefits.

In WP1, the key aspects concerning bearing design for both current running gear designs and novel concepts that are still in the development phase were investigated (novel alloys and steel grades for bearing rollers and races, novel polymer materials for bearing cages, the geometry of components and lubrication solutions that may provide longer life for the lubricant, i.e. today's key element for the lifetime of the bearing). This initial study was completed in the first five months of the project and all the specific objectives have been achieved. After a preliminary assessment, a short-list of technology concepts was produced to be retained as potential contributors to the GEARBODIES Design Concepts, which can be developed further. WS2.2 will adopt 2 approaches – a "focused" Design Concept (higher TRL) through radical changes in roller-race geometry and lubrication concept, which will conclude with a bearing prototype tested according to standards, and "open" Design Concepts (at lower TRL, investigated through modelling and experimentally in laboratory), including the use of advanced materials for bearing critical parts (rollers, races and cages), more radical lubrication solutions (active or passive), etc. The next step was to set out the high-level user requirements which are consistent with SHIFT2RAIL's System Platform Demonstrator 1 (SPD1), such as functional and operational requirements, RAMS and LCC requirements, requirements regarding compliance with standards and regulations, and performance requirements (KPIs). Finally, the specifications for a higher-TRL bearing Design Concept and lower-TRL Design Concepts were set to be further refined and developed in the remainder of the project's duration.

In WP4, an AHP analysis method with three levels was carried out and applied to select the most feasible solutions for improving the LCC and enhancing the life-time of rail vehicle running gear components. (fig. 8)

The 1st level was the assessment of specific objectives; the 2nd level, impacts of improvement criteria; and the 3rd level, potential solutions (alternatives) were explored.

FIGURE 8
AHP structure for choosing solutions to improve the LCC in journal bearings



A Multi-Body Simulation (MBS) benchmark model was developed to assess the loads (based on EN 12082 standard) that journal bearing components must endure to evaluate the impact of the component innovations. In WP7, this model will be equipped with the components developed in the meantime to investigate their impact on vehicle performance.

In WP6, the concepts and requirements identified in WP1 and refined in WP4, will be investigated, developed and tested for the selected specific solutions (including materials, lubrication and optimisation of component geometry) for the integration of the most feasible ones into a novel bearing design that will be prototyped and tested in WP7.

Regarding novel roller-race materials, potential candidate High Entropy Alloys (HEA, Fig. 9), as coating material have been selected based on Hume-Rothery (HR) rules. An initial selection of 39 possible alloys was narrowed down to 4 possible candidates using DFT (Density Functional Theory) with the Quantum Espresso software. The preparation of samples for laboratory testing is ongoing.

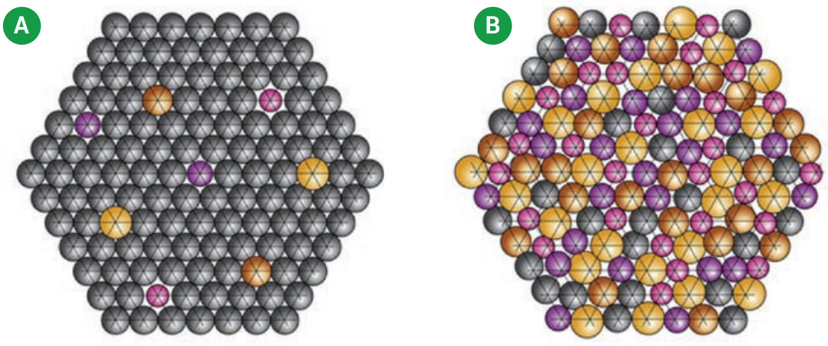


FIGURE 9

Schematic diagram of a) conventional and b) high entropy alloy

According to preliminary investigations of novel lubrication solutions with oil, work on housing solutions is more promising than work on bearing sealing solutions. The latter shows higher difficulties in containing lubricant leakage and high costs for developing required sealings. Investigations on journal bearing component geometry optimisation has also been carried out on different aspects of design such as roller and cage geometry and better surface tolerances.

The investigation will develop the selected technology concepts for bearing lubrication to a point necessary for the concept design and prototype. The approach is to use the current state-of-the-art lubricants in novel ways. The most suitable state-of-the-art lubricant for the concept design will be identified depending on the lubrication concept(s) that prove to be suitable for combination with the other technological developments (materials, geometries) (Fig. 10).

In parallel work, the oil and grease lubricants are being investigated in combination with different polymers to identify differences in polymer ageing behaviour. Injection moulding of the polymer samples is being done according to ASTM D790, which recommends the geometry for subsequent mechanical tests. The ageing tests are carried out according to the ASTM D543 Standard. The mechanical tests (tensile and 3-point-bending) are to be performed before and after the ageing test to evaluate the differences.

The findings of WP6 tests and investigations will lead to the finalisation of the GEARBODIES journal bearing Design Concepts.

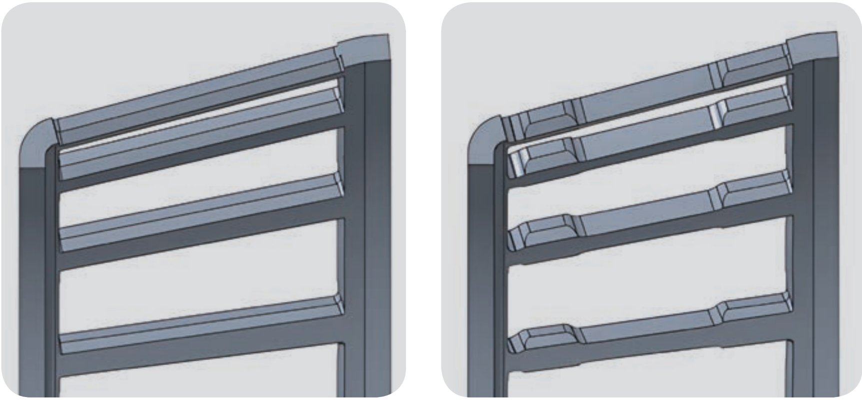


FIGURE 10

Optimized geometries for the cage

FACTS AND FIGURES

Budget
2.4M

Duration
25 Months

13 Partners from
7 EU countries

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01.12.2020

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