Executive summary (not exceeding 500 words)

Demand of high performance rubber composites in the tyre industry is increasing exponentially in order to meet the challenges such as superior performance properties, strict environmental and safety requirements , low carbon footprint etc. These composites consist of widely varying materials : particulate fillers like carbon black and silica , rubbers , fabric and steel cord . The properties of the consolidated composites would depend on the properties of individual materials , their compounding as well as adhesion between the components. Recently , a host of new generation fillers, rubbers and reinforcement materials have been developed and some traditional materials have been taken up for further improvement . However, their combined effect on the properties of a product like tyre in different categories is still in its nascent stage in India. The main advantages of using high performance composites would be improved durability , weight reduction, recyclability and special properties such as lower rolling resistance , lower fuel consumption, higher abrasion resistance and reduced tyre noise as compared with the traditional materials. The proposed project would focus on development and properties of high performance rubber based composites using new generation rubber, fillers, compounding ingredients and reinforcement materials such as steel cord , with particular reference to tyre industry. The proposed project would also look into modeling and failure analysis and their comparison with the existing materials .
The project would be carried in consortium mode where companies manufacturing rubber, fillers , steel cord , rubber compounding ingredients (Tata Steel, SKI Carbon Black India Pvt. Ltd. , Techno WaxChem Pvt. Ltd., AcmeChem Ltd.) and two tyre companies -(HASETRI, JK Tyre & Industries Ltd. for passenger car and truck-bus radial and BKT , Balkrishna Industries Ltd. for Off-the road tyres) would be involved. An independent tyre testing laboratory (IRMRA) would also be associated. The research work will be carried out jointly in the Rubber Technology Center in consultation with these companies who would translate the knowledge to manufacture tyres meeting the latest specifications on rolling resistance , fuel consumption and abrasion resistance .

Background and motivation (not exceeding 500 words)

India is one of the world's fastest growing economies, 9th largest economy in the world (nominal GDP) and projected to become the world's 3rd largest economy with GDP at $13,716 bn. In global perspective , India ranks as 5th heavy truck manufacturer, 6th passenger car manufacturer and 1st tractor manufacturer. By 2026, the units of passenger vehicles are likely to increase between 9.4 - 13.4 million, commercial vehicles between 2.0 - 3.9 million, two wheelers between 50.6 - 55.5 million, and tractors between 1.5 - 1.7 million [1]. The Indian auto Sector will account for over 12% of India's GDP, and generate an additional 65 million jobs and is expected to meet the dream of the Prime Minister for making in India.
However , this industry is very dynamic and vibrant because of changing customer needs. The tyre sector is a part of the automotive manufacturing industries and as a result , is continuously upgrading itself with the latest technologies for meeting widely varying requirements. There are a few challenges before the tyre industry : 1) to meet higher fuel efficiency, environmental, and performance demands at competitive costs. 2) to comply with tyre labelling criteria for passenger cars and light trucks that have taken effect from 1 /11/ 2012 under European Regulation (EC) No. 1222/2009 bringing a major advance in consumer information on tyre safety (wet braking) and the tyre's impact on the environment (rolling resistance and external noise). 3) to produce tyre with low carbon footprint 4) to utilize sustainable materials 5) to emphasize recyclability 6) to explore use of smart materials and 7) to develop lighter weight steel cord [2] .
Material development plays an important role against this background, since significant weight decrease is made possible through the substitution of high density materials and more precise adjustment of material parameters to the functional requirements of the components. For example, lighter weight vehicles could be manufactured by using appropriate fillers at reduced quantity. High strength steel of reduced diameter could decrease the weight of a tyre. Since tyre is a composite product, seamless interaction among the components is very important for overall properties of a tyre. In addition , launch of National Electric Mobility Mission Plan (NEMMP) and Faster Adoption & Manufacturing of Electric (& Hybrid) Vehicles (FAME India) to promote hybrid and electric vehicles pose further challenges.
It is also interesting to see that most of car manufactures in the world has set up manufacturing units in India. It is imperative that the tyre manufacturers would need advance technology to meet the requirements of the world. Although a few companies are developing novel materials and technology, its pace is to be increased with strong basic understanding for future technology development. The current project would fulfill these aspects, bringing all the relevant companies under one umbrella.

References :
1. Personal communication dated 28th September 2015 with Mr. Rajiv Budhraja, Director General, ATMA New Delhi
2. Current Topics in Elastomers Research, Edited by Anil K . Bhowmick, CRC Press , USA , 2008

Project outcomes (please list specific objectives): *The project should address a specific need of the industry/industries and there should be clear expected outcomes from the project. It is expected that joint patents will result from this project.*

- Development of rubber compounds to meet specifications of future tyre i.e. low rolling resistance and higher fuel economy. The materials would be selected from the participating industries (Tata Steel, SKI Carbon Black India Pvt. Ltd. , Techno WaxChem Pvt. Ltd., AcmeChem Ltd. , IRMRA) . If required, the industries would be advised to upgrade the properties of their materials.
- Understanding of interactions of novel compounding ingredients and fillers (carbon black , nanofillers and silica) to be used above by using Design of Experiments at IIT Kharagpur .
- Studies of the properties (like Tensile Strength, Tear Strength, Fatigue, Abrasion, Dynamic properties etc.) of the rubber compounds and vulcanizates in the Rubber Technology Center.
- Studies of adhesion among the components (although tyre appears black, there are different components and associated materials). In addition, rubber to steel cord bonding is very important in such components. These studies would be done in IIT as well as in the participating industries (Tata Steel , JK Tyre & Industries and BKT).
- Processing of the compound in the Industry and scaling up (JK Tyre & Industries and BKT).
- Development of tyre in the laboratory and testing of properties (JK Tyre & Industries and BKT) .
- Manufacturing of tyre in the Industry and property measurement of slabs at IIT Kharagpur.
- Testing of tyre in the laboratory and field by the industry(JK Tyre & Industries, IRMRA and BKT) .

Scope (not exceeding 1500 words): *The scope should clearly lay out the contributions of the academic partner and the industry partner.*

With the advent of new technologies, emphasis is laid upon by the different research and development wing of industries and academia for the development of energy efficient materials and technology . Among the different materials that are being commonly used in our society on a daily basis, the contribution of polymeric/elastomeric materials has been peerless. However, owing to the poor performance of the neat polymer/elastomer, it is often compounded with a variety of fillers to develop polymer/elastomer composite material. Out of the different class of polymer/elastomer composites that are being used regularly, tyre is known to be the most complex polymeric/elastomeric composite ever developed. Apart from elastomer, development of tire involves a conglomeration of materials like fillers, steel cords, fabric, etc. In line with the other agencies, the tyre industries are also focused to develop tires which can effectively increase the fuel efficiency (energy efficient tires).Under such circumstances, a judicious selection of compounding ingredients is required. With the current perspective that is prevailing in India, there is tremendous growth in the economy and is projected to become the world's third largest economy within the next few years. The contribution of the automotive sector towards the economic growth of the country has been phenomenal. Globally, the Indian automobile sector is considered as a heavyweight player. Despite a sluggish business in the Indian automotive sector for the past one year, it is projected that there will be potential improvement in the automotive market in the upcoming years. The impact of such an improvement is going to be directly translated on the Indian tire industries. Following that, there is potential growth of research work in the R& D of the Indian tyre industries .

Tyre business in India is mostly classified in the development of passanger/truck-bus tyre and off -the -road tyre. However, among all the class of tires that are produced in India, the two-wheeler production is the most dominating segment in the Indian automobile market. As a result, it is noted to be the flag bearer for the majority of the shares in the automobile industry of the country. According to "India Tyre Market Forecast & Opportunities, 2019", the level of radialization of tyres in medium and heavy commercial tyre segment continues . Various government projects like Golden Quadrilateral project, North-south and East-West corridors and various state highway projects are currently in the execution stage, and the completion of these projects is expected to significantly boost the demand for radial tyres in the country in coming years. Also, implementation of stringent laws on overloading by the government is expected to put pressure on transporters for using radial tyres instead of traditional cross- ply tyres. Thus, in order to revamp the radial tire business in India, a proper research work related to the ingredients involved in the preparation of radial tire becomes essential. However, the major impediment in achieving in achieving such a goal from the industrial R& D alone, is the lack of potentially skilled worker and technology. Thus,an innovation framework via R&D, academics and technical / manufacturing activities is becoming popular day by day. Academic centers are the best nodal agencies to work with multiple industries. Thus, it is envisioned that such a target can be achieved through a consortium between industries and the academia.

In this project , eight participating industries have been identified. These range from major raw materials suppliers and testing to tyre industries with R & D capabilities (Tata Steel, SKI Carbon Black India Pvt. Ltd. , Techno WaxChem Pvt. Ltd., AcmeChem Ltd. , IRMRA) to the manufacturing industries with strong R& D capabilities (JK Tyre & Industries and BKT).

The rubber compounds would be developed to meet specifications of future tyre i.e. low rolling resistance and higher fuel economy. The materials would be selected from the participating industries (Tata Steel, SKI Carbon Black India Pvt. Ltd. , Techno WaxChem Pvt. Ltd., AcmeChem Ltd.) . If required, the industries would be advised to upgrade the properties of their materials. Interactions among novel compounding ingredients , rubber and fillers (carbon black , nanofillers and silica) would be studied using Design of Experiments at IIT Kharagpur . Investigation of the properties like tensile strength, tear strength, fatigue, abrasion, dynamic properties etc. of the rubber compounds and vulcanizates would be carried out in the Rubber Technology Center. Adhesion among the components (although tyre appears black, there are different components and associated materials) would be investigated in details . In addition, rubber to steel cord bonding is very important in such components. These studies would be done in IIT as well as in the participating industries (Tata Steel , JK Tyre & Industries, and BKT). Once the rubber compounds meet the laboratory properties , these will be subjected to processing and scaling up in the Industry (JK Tyre & Industries and BKT). Prototype tyre would be made in the laboratory and the conventional properties would be tested at JK Tyre & Industries , IRMRA and BKT .Different class of tyres would be designed and made in both the Industries, Simultaneously , measurement of properties of slabs taken from tyre would be carried out at IIT Kharagpur. The developed tyre would be tested in the laboratory by the industry (JK Tyre & Industries and BKT) . Subsequently, these will be subjected to field trials before commercialization.

Work Packages and Timeline (use tables/Gantt charts): *The key tasks must be listed in the form of work packages with timeline (start and end month from the date of start of the project) and identify who will hold the prime responsibility for each work package and where the works will be conducted.*

0-6 months	IIT KGP	Literature Search, Concepts & ideas Procurement of laboratory materials
	Industry	Development of compounding ingredients, fillers and steel cord for lower rolling resistance , higher abrasion resistance and lighter weight rubber compounds.
7-12 months	IIT KGP	Model experiments in the laboratory & formulation development using the developed materials
	Industry	Experiments to check the level of superiority of the developed materials.
13-18 months	IIT KGP	Development of composition from the supplied materials , Processing aspects of compositions And Adhesion tests with steel cord . Design of experiments
	Industry	Formulation and process trials concurrently in the industry
19-24 months	IIT KGP	Properties of rubber composites with reference to specification and objectives
	Industry	Trial of IIT developed compounds in the industry, suitable modification , if necessary , tire fabrication in the laboratory, process optimization
25-30 months	IIT KGP	Tests of samples taken from the industry . Simulation studies
	Industry	Manufacture of tire in the factory and testing
31-36 months	IIT KGP	Report writing
	Industry	Field trial and commercialization

Key Milestones (six monthly): *List the key six monthly milestones.*

0-6 months
Literature Search, Concepts & ideas
Procurement of laboratory materials
Development of compounding ingredients, fillers and steel cord for lower rolling resistance , higher abrasion resistance and lighter weight rubber compounds.
7-12 months
Model experiments in the laboratory & formulation development using the developed materials
Experiments to check the level of superiority of the developed materials.
13-18 months
Development of composition from the supplied materials , Processing aspects of compositions And Adhesion tests with steel cord . Design of experiments
Formulation and process trials concurrently in the industry
19-24 months
Properties of rubber composites with reference to specification and objectives
Trial of IIT developed compounds in the industry, suitable modification , if necessary , tire fabrication in the laboratory, process optimization
25-30 months
Tests of samples taken from the industry . Simulation studies
Manufacture of tire in the factory and testing
31-36 months
Report writing
Field trial and commercialization

Plan for commercialization (not exceeding 500 words): *The industry partner should show a clear path to commercialization if the proposed work is successful. (letter/communication from the industry partner may be scanned and uploaded)*

Commercialization of tyre usually involves several steps. After the initial research and development, prototype tyre is to be made. In this project , two companies would make the tyre of different sizes. These will be then subjected to laboratory tests. The properties would be compared with those of conventional tyres. If the process is successful , tyres would be subjected to field trials. If not, further improvement would be done on the compounds and the composites. After successful field tests , commercialization would be done. Letter from various participating industries has been received.