

thetic), thickener (soap or non-soap), solid lubricants and additives. Friction and energy loss are governed by friction modifiers in the form of solid lubricants. The current generation of friction modifiers are micro-ground solids which provide the advantage of a transparent film over the gear teeth.

Work has been done on developing 'green grease' which can be effectively broken down by microorganisms present in the soil, atmosphere or water bodies into non-toxic and harmless by-products within a reasonable time. But cost is a factor – all bioproducts are ~1.5 times costlier than conventional products.

Emerging trends comprise of: (i) the use of non-soap thickeners (inorganic gels, clay or polyurea) in place of metallic soaps or complexes (Ca, Al, Li) for high-performance greases; (ii) looking at life-cycle cost instead of purchase price and trying to quantify intangible benefits; (iii) new business opportunities in

waste management, green lubricants and specialized technical services.

Testing of lubricants

V. Martin (IOCL R&D Centre) described various test methods for performance evaluation of lubricants on rigs, encompassing short-duration tests for antiwear and extreme pressure, long-duration tests for antiwear, grease durability/life and leakage tendencies, and special purpose test rigs. He pointed out that though some tests are not satisfactory, they are still run because of industry requirements.

R. T. Naik (IISc) explained different standard tests for eco-friendly lubricants. He emphasized that the test procedures should be internationally recognized and standardized, and that the test results should give an unequivocal measure of ultimate biodegradation. He also stressed that the test conditions should not be so stringent as to fail useful, readily biode-

gradable products. Careful monitoring, sample purity and suitable test conditions to suit specific applications are necessary.

1. From Kailas' lecture at RAIEFL-2010.
2. Mannekote, J. K. and Kailas, S. V. (review article submitted to *Tribology Online*).
3. The ASTM standard D 6384 definition for ultimate biodegradation states that degradation is achieved when the test material is totally utilized by microorganisms, resulting in the production of carbon dioxide, water, inorganic compounds, and new microbial cellular constituents (biomass or secretions, or both).

ACKNOWLEDGEMENT. I am grateful to Mr J. K. Mannekote, Department of Mechanical Engineering, IISc, Bangalore for explaining the related technical jargon.

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MEETING REPORT

Transport networks for India*

Demand for transport in India is growing at around 10% p.a. for more than a decade, whereas supply of transport infrastructure and services has not been able to keep pace with demand and is proving to be a drag on the economy. Although road transport is the most favoured mode of transport, road infrastructure capacity will not be able to keep pace with transport demand. A major issue has been that most of the Indian transport infrastructure is developed on mode-specific and regional policy premises. We need an integrated transportation system planning for sustainability of the transport system in India.

In this backdrop, a one-day workshop was held recently at CiSTUP, IISc, Bangalore. The main objectives were to (i) review infrastructure and service markets

of all modes of transport in India employing a systems approach; (ii) identify key issues and challenges within and between transport modes in India; and (iii) recommend directions for further research for realizing a comprehensive multimodal transport infrastructure and service network at the national level.

B. N. Raghunandan (Department of Aerospace Engineering, Indian Institute of Science (IISc), Bangalore) emphasized the importance of the transport sector in modern economies and its role in stimulating economic growth in peripheral regions in India. T. G. Sitharam (Centre for Infrastructure Sustainable Transport and Urban Planning (CiSTUP), IISc) highlighted the inadequacy of transport infrastructure, lack of skilled manpower and shortage of data for monitoring systems as the major challenges confronting the Indian transportation system. He informed that in the XI Five-Year Plan, infrastructure investments have doubled from the previous Five-Year Plans constituting up to 9% of GDP. The present Plan offers a bigger role for private participa-

tion in infrastructure development by allowing 30% FDI in infrastructure investment. He also described the major projects planned under the XI Five-Year Plan in each transport mode.

Speaking on the Indian air transport networks, Kota Harinarayana (National Aerospace Laboratories (NAL), Bangalore) identified three typical passenger travel trends, viz. average daily passenger travel times in most cities are around 1.2 h, mobility of passengers/goods increases proportionally with GDP per capita, and modal shift from slow to fast transport modes takes place when the national economy evolves from agriculture to industry to service-based economies. In terms of air connectivity, India has 86 operational airfields out of a total of 449. If all airports are made operational, then two-thirds of the Indian population will be within 50 miles of an airport. Presently, 70% of the total Indian air traffic is between Delhi, Kolkata, Mumbai, Bangalore, Hyderabad and Chennai. The Airports Authority of India has undertaken development of 50 non-metro

*A report on the one-day workshop on 'Transport Network for India: Vision 2020', held on 22 April 2010 at the Centre for Infrastructure Sustainable Transport and Urban Planning, Indian Institute of Science, Bangalore.

airports with the help of private participation to improve regional connectivity and promote tourism.

M. N. Sreehari (RV College, Bangalore) discussed the present state of road infrastructure in India, road network expansion programmes initiated by the Indian Government and present strategies adopted by the Planning Commission to improve the Indian road transport sector. The total Indian road network is believed to be the second largest in the world with the national highways accounting for 2% (72,382 km) of the total road networks, carrying nearly 60% of road freight traffic and 87% of passenger traffic. A massive road expansion programme is underway in various governmental schemes for developing road networks, with a target to connect all village roads with the main road transport corridors. Sreehari identified rising road fatalities, inadequacy of budgetary allocations for infrastructure expansion, slow progress in rural connectivity programmes and lack of oversight of overloaded trucks plying on highways as causes for concern in the Indian road sector. He recommended the establishment of a national agency to expedite rural road projects.

Ravibabu Manchala (Indian Railways and RITES) discussed the Indian rail scenario. He stated that the Indian Railways account for 36% of inter-regional freight flows, primarily catering to the industrial bulk market segment, where transportation of large volumes over long distances is desired. He mentioned that rail freight infrastructure expansion has progressed slowly because of many challenges such as land scarcity, land acquisition delays, inadequate project funding and a large number of socially desirable but economically unviable rail projects.

Manchala proposed institutional changes for establishing partnerships between state and city authorities to develop urban rail infrastructure.

Deepak Baidur (CiSTUP, IISc) explained how Indian coastal shipping and waterways transport lost its dominance

gradually as policy focus shifted to the road and rail modes after independence. India's Inland Waterway (IWW) network shrunk from 28,000 km before 1971 to only about 3800 km of navigable waters in 2008. River navigability remains hazardous due to shallow depths, inadequate navigational aids and poor upkeep of navigational charts. Baidur's recommendations were towards linking seaports to IWW, wherever possible, to limit the number of modal transfers. Secondly, updating laws and regulations governing coastal shipping and IWW taking into account the present market conditions and industry needs. Finally, a systematic collection of shipping data to monitor, plan and manage water transport activities in India.

Ashish Verma (CiSTUP, IISc) discussed about implementing intermodal transport in the Indian cities. He observed that the Indian cities are unable to meet the increasing travel demand because of the prevailing imbalance of modal split in favour of private vehicles. Verma explained that systems integration of public transport can be brought about by integration at institutional, operational and physical levels to optimize the complete origin-destination (o-d) travel time of the user. Only then would a user find public transport more attractive than a private vehicle for urban commute.

An inter-disciplinary panel identified major thrusts in transportation infrastructure and research needs. G. Kalpana (IAS) argued that public policy issues could be effectively addressed by ensuring integration, coordination, capacity-building and tapping of external resources by the governing institutions through suitable mechanisms. Rishikesh Krishna (Indian Institute of Management, Bangalore) argued that an urban city body should be distinctive and function as an integrated and cross-sectoral decision-making authority to address urban issues. He also urged private and public stakeholders to proactively engage in city

affairs and find innovative solutions to local problems.

Anurag Kumar (Department of Electrical Communication Engineering, IISc) showcased the skills and expertise in operations research and ICT technologies in his Department, thereby introducing transportation research areas where they could effectively contribute. P. R. Mahapatra (Aerospace Engineering Department, IISc) reviewed the pros and cons of the different transport modes and argued that medium-speed railways is the most appropriate transport mode to form principal arterial networks in India. R. Srinivasan (Department of Management Studies, IISc) stressed that different transport modes need to be managed under one institutional set-up to facilitate better coordination and planning of intermodal transport projects.

S. Gangopadhyay (Central Road Research Institute, New Delhi) highlighted issues in transport infrastructure planning and data collection for traffic analysis. He stressed the importance of safety audits for city roads and concluded by suggesting new methodologies for collecting traffic data. Satish Chandra (NAL) argued that research tools and policy measures in transportation should keep pace with changes in the society to stay relevant and acceptable with times. Narayan Rangaraj (Indian Institute of Technology Bombay, Mumbai) stressed on the importance of inclusive overall transportation development by developing better transport connectivity in tier II and III cities to unburden metro cities, thus promoting a balanced, safe and sustainable strategic approach for the future.

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