An Optimized **Transport Concept for Tractor-semitrailer Combination**

The article describes the activity carried out by Iveco in the study and development of an optimized transport concept, starting from the latest proposals of transport solutions. The goal of this concept is to realize a prototype vehicle (tractor and semitrailer combination for long distance mission) that could, on one side, improve the load capacity in terms of volume and weight by means of an extended length semitrailer (up to 18 m), minimizing, on the other side, the fuel consumption.

1 Introduction

It is known that in the coming years, due to the economic growth that will bring more mobility, the EU will have to face an on-going increase of transportation demand of goods (+38%) and passengers (+24%) [1], **Figure 1**. The big challenge for the whole on-road transportation system, in the future, will be therefore to provide the best performances in terms of capacity, safety and sustainability [2]: heavy duty vehicles will play an important role in improving and optimizing such issues. That will be possible through dedicated and focused developments, in order to implement new solutions and systems, enabling a more efficient and accepted use of heavy trucks for road transportation of goods.

2 Actual and Future Situation in the European Road Transport

2.1 Transport Scenario

From the European Commission White paper issued in 2001 the following still topical main issues are highlighted. The growing conflict facing transport is an increasing demand for mobility (goods and passengers) versus environmental needs and safety challenges.

Such aspects are caused by the European trend in terms of growth of the GDP [3]: a foreseen growth of almost 70 % in the next 20 years, due partly to the economies of western European countries, but mostly of East Europe, will bring to increasing transport fluxes in the two main corridors (North-South and West-East) and to a redistribution in the freight transport activities. If nothing will be done, this will result in an increase of the heavy goods traffic of 50 %; on top of that there will be a big risk of losing competitiveness and of more costs (1% GDP by 2010 for roads and 2% for safety problems).

The second main issue is the relationship between transportation and sustainable development. It is known that the transport emissions are 28 % of global CO_2 emissions and, in particular, the 84 % of those are generated by the road transport: if nothing will be done an increase of CO_2 emission is expected (up to 50 %).

That is an opposite trend compared to all the others gaseous emissions that are reaching sustainable levels in the next years due to the Euros Directives.

2.2 Fuel Issues

The main topics related to the fuel can be summarized as follows: Crude oil availability: the peak of production will be reached between 2010 and 2015 and there will be the need to exploit more and more expensive reserves (i.e. deep sea or oil sand) Crude oil price: the price doubled from 2004 to 2006 (up to 80 $/barrel) and a structural price increase has happened within the last few month up to nearly 100 $ / barrel, due to the demand/offer ratio. Security of supply: the transport is 98 % dependent on oil, 70 % of which is imported (EU).

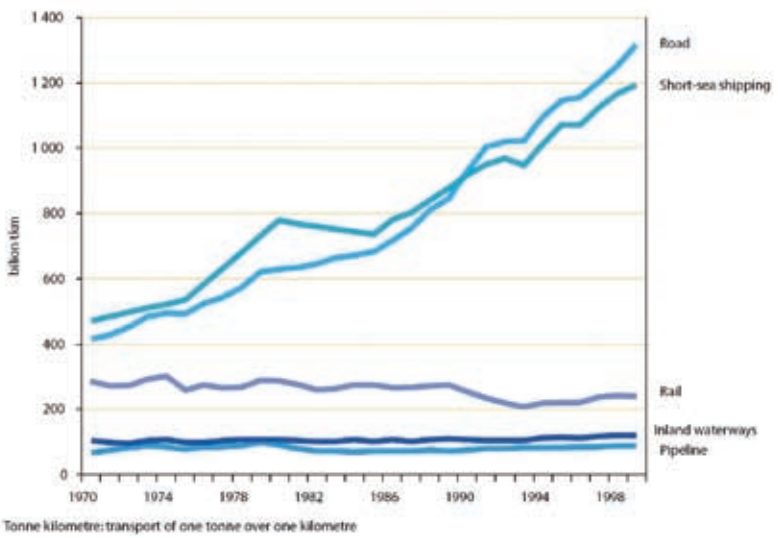

Figure 1: Goods transport: Growth of traffic by mode of transport, EU-15: 1979-99 [1]

3 Iveco Transport Solution

Following the latest proposals at European level, Iveco studied the feasibility of a vehicle solution aiming to maximizing the effectiveness from freight transportation point of view, and minimizing at the same time the impact from a global point of view. The target was to create a matching between the European freight operators' asking for economical returns and the EU Commission's concerns about environmental and infrastructural sustainability.

The tractor + semitrailer vehicle configuration was chosen, since it's the most widespread in freight transport.

To meet the objective two main directions have been taken:

- Increase in transport capacity with additional vehicle length and reduced tare weight
- Increase in fuel efficiency by means of aerodynamic and mechanical optimization and reduction of the rolling resistance due to tires.

The effects and global benefits can be summarized as in **Figure 2**: the enhanced load capacity can bring to a global reduction of circulating heavy duty vehicles; in combination with fuel efficiency, re-

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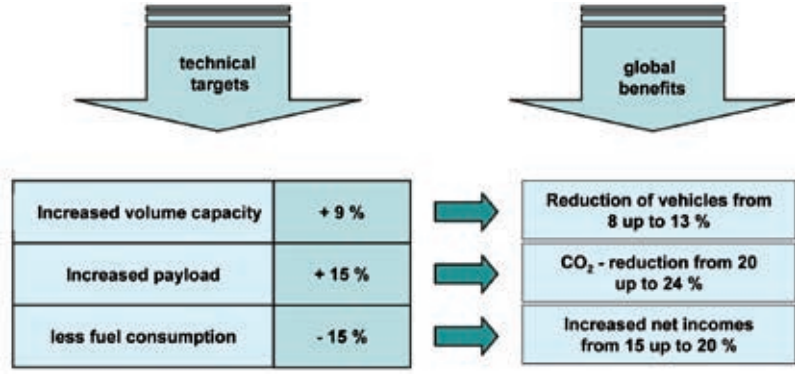

Figure 2: Targets and global benefits of the Iveco transport solution

duction of emissions (up to 24 %) and added incomes for fleet operators are achievable.

3.1 Transport Capacity Enhancement

The analyzed and tested concept consists of a 4x2 tractor+semitrailer vehicle combination, dedicated to long distance missions, with an extended length up to 17,8 m, by using a 15 m semitrailer (ISO 45/48 ft possible), with a standard height of 4 m and a GCW of 40 or 44 tons (according to the different EU countries legislations), **Figure 3**. Such solution can maximize the transport efficiency with minimum changes, with respect to the requirements of the EU Directive 96/53CE. The extra 1,3 m allows an increase of load capacity of 9 % in terms of volume (i.e. the capacity in europallets, that means from 33 to 36 pallets); while the possible extra 4 tons allow an increase of 15 % in terms of weight of transported goods. Main concerns about such a vehicle are about its manoeuvrability and its worse road wear effect (if the 44 tons are considered).

Regarding the latter issue, being the damage effect proportional to the 4th power of the axle load, such increase could give an important drawback: it has to be taken into account, anyhow, that in many EU countries a GCW > 40 tons is already legal.

3.2 Transport Efficiency

The starting point of the work has been the well-known physics of the vehicle, **Figure 4**.

The main datum lies in the significant roles of aerodynamics and, obviously, of rolling resistance. It's worthwhile to underline that this power balance is valid for long-distance motorway contexts, target of the considered solution, since in this case the heavy duty vehicle doesn't need significant power for climbing resistance or for acceleration, and travels at a cruise speed of 85 km/h imposed by the prescribed speed limiter.

3.2.1 Aerodynamic Optimization

A CFD simulation programme has been carried out on a complete tractor + semitrailer convoy, the target of which was to analyze the significance of several aerodynamic optimization on the whole configuration. By the end, a robust know-how on main aerodynamic problems was collected:

- Back negative pressure
- disturbs of the air flow due to the gap between the tractor cab and the semitrailer front wall
- disturbs due to wheel of the tractor front axle and of the semitrailer axles
- disturbs due to mirrors.

Because of such problems the following optimization interventions have been designed and fixed after the simulation process.

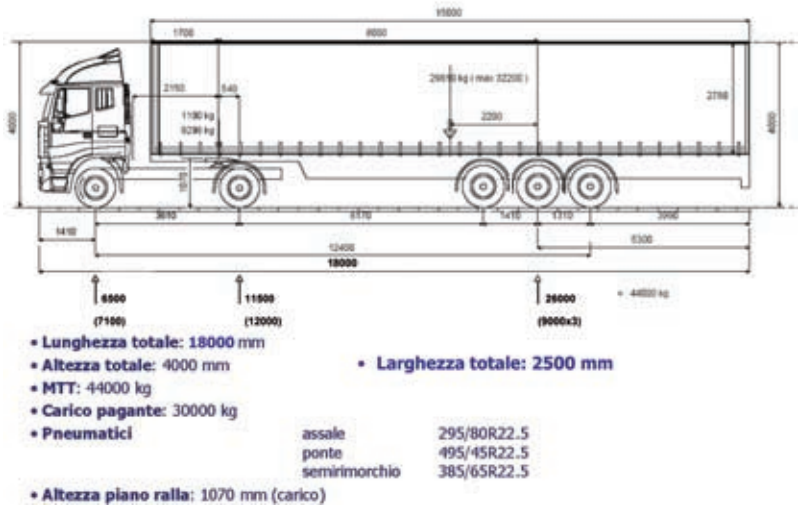

Figure 3: Iveco transport solution for enhanced load capacity

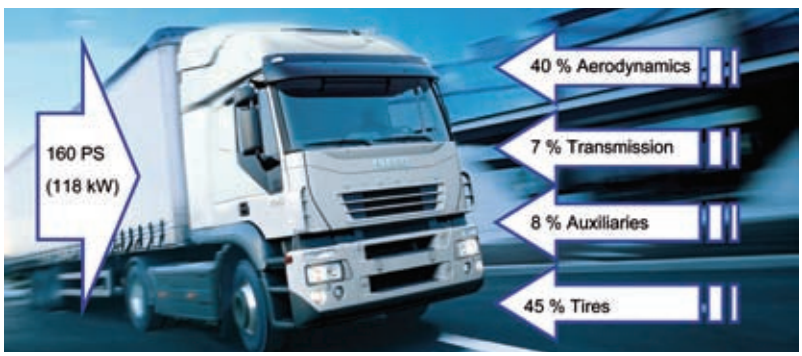

Figure 4: Average distribution of power request for 40 t vehicles (long distance motorway application)

3.2.2 Tractor

- Front lowered bumper with optimized shape dam
- mobile spoilers behind cab to reduce the effects of the cab-semitrailer gap
- lateral lowered sideskirts and rear wheel coverage
- higher cab roof.

3.2.3 Semitrailer

- Mobile spoiler extensions behind the semitrailer
- aerodynamic floor on the bottom of the semitrailer to canalize the air flow
- lateral sideskirts with air intakes and flux guides
- convergent extractor with baffles and diffuser on the back of the semitrailer
- new rear under-run protection cross member profile.

Such choices, as is described below in the description of testing activities, brought to a global reduction of the longitudinal drag coefficient of about 22 %, split among the several modifications as shown in **Figure 5**.

In particular, mobile spoilers have been realized with an innovative technology that used inflatable special rubber materials, with an integrated approach on the serial production pneumatic system of the vehicle (patented solutions).

Particular attention has been dedicated to the aspects related to manoeuvrability between tractor and cab (since the mobile spoilers between them could create interference) and to the functionality of the semitrailer doors, since the rear extension were installed on them.

A control logic with a prototype ECU has been thus developed: the idea is to have such mobile extensions open during high speed, straight normal driving in motorways and closed during low speed driving and turning manoeuvres (patented solution).

The CFD analysis, **Figure 6**, has been performed with the commercial code Fluent and took advantage from its validation with historical experimental data collected by Iveco in the DNW wind tunnel that brought to a correlation error of 3 % between simulation and wind tunnel.

In addition, the analysis has been followed by the design and realization of new aerodynamic parts, prototype vehicle set up, and, finally, testing on road for the evaluation of real benefits, both in terms of drag coefficient and fuel consumption reduction.

The following tests has been performed on Iveco track proving grounds (April 2006):

- Coast-Down
- fluidodynamic field visualization with wool threads
- static and dynamic pressure experimental acquisition in key areas of the vehicle surface
- cruise speed tests fuel consumption.

The results of the experimental analysis underlined the big contribution in the improvement by the rear extensions (particularly efficient thanks to the diffuser and the underneath canalization), good feedback came from sideskirts of the semitrailer and from the cab-semitrailer gap closure, and, finally, interesting results from the new shapes of tractor's sideskirts and front bumper were noticed.

In total, aerodynamic on road response resulted in a reduction of longitudinal drag coefficient of about 22 %, which can be translated [5] into a fuel consumption reduction of about 7 %.

These outcomes are to be considered significant, since the aerodynamic performance can improve with side wind conditions up to -6 % more of drag coefficient, meaning about 2 % of fuel gain.

3.2.4 Powertrain and Auxiliaries

The target concept vehicle has been equipped with: Turbo "Double Stage" Cursor 10 engine, 500 hp at 2100 rpm, already respecting Euro 5 regulations and developed in Iveco Powertrain research centre

- Advanced engine cooling management with controlled water pump (visco)
- optimized rear axle (bearing, oil)

Figure 5: Aerodynamic optimizations on the tractor-semitrailer combination (tested improvements on drag coefficients are put in evidence)

- optimized Steering pump (controlled, VarioServ)
- optimized alternator (ratio, characteristic)
- optimized air process unit (EAC)
- optimized fan (controlled, visco).

3.2.5 Rolling Resistance

Rolling resistance reduction is up to tyres optimization, and, on this side, the choice has been to adopt:

- "Super Single" tyres instead of twin tyres on the driving axle (reduction of contact surface in combination with reduced weight)
- tyres with optimized tread patterns and compound on the front axle of the tractor and on the semitrailer's axles.

3.3 Acceptance and Safety Issues

In order to increase the level of preventive safety in the use of the vehicle and considering the criticalities that can increase with a longer vehicle combination, it is fundamental to guarantee a complete support to the driver during his driving tasks.

The proposed concept solution has been equipped with the most effective and up-to-date ADAS systems, in order reduce the risks of accidents in dynamic conditions and reduce the workload of the driver:

- Stability control (ESC)
- tyre pressure monitoring (IVTM)
- advanced Cruise Control (ACC 2nd generation, integrated brake management)
- lane Warning (acoustic warning)
- active Lane Assistant (haptic warning)
- Blind Spot Detection (front camera + display, to cover and extend category 6 field of view, mandatory since 1/2007)
- Lane Change Assistant (left camera + acoustic warning, to recognise overtaking vehicles).

Concerning the semitrailer contents the main task was to increase its compatibility with other road users:

- Rear camera (with in cab display)
- rear ultrasonic sensors
- indicators lights alongside the semitrailer
- anti-spray effect of the side skirts (active and passive visibility)
- reflecting stripes (side and rear).

Figure 6: CFD analysis results (isosurfaces of total pressure) of (a) the serial production and (b) optimized concept vehicle

4 Verification

Each of the three areas of optimization has been quantified in terms of fuel consumption reduction with dedicated tests; besides specific tests for aerodynamic, as previously mentioned, extended test campaigns on tracks motorways and country roads were conducted during 2006 and are summarized in the **Table** in terms of fuel usage eduction split.

Global tests in German motorways (June '06) registered a global fuel usage reduction of 15 %.

5 Conclusions

The article has described the activity carried out by Iveco in the study and development of an optimized transport concept, starting from the latest proposals of transport solutions.

European concerns about sustainability of the future on road goods transport have been deeply taken in account and, with an approach that combined fuel efficiency and greater load capabilities, important goals have been reached both from an environmental and an industrial perspective. Particularly, the gain of 15 % in fuel economy and 9 % in conveyable pallets can rise an interest in the customers to create a pull-demand for future work on new transport solutions for heavy duty commercial vehicles. The outcome is a possible solution, with a big potential level of acceptance and with an effective and positive impact on the transport world, from a global point of view.

References

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Table: Real tests on German motorways registered an over all fuel reduction of 15 %

Aerodynamics	-7/-8 %
Engine	-2/-3 %
Auxiliaries & Driveline	1 %
Rolling Resistance (tyres)	-3/-4 %

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