

Transfer of technologies from developed to developing countries: experiences and results in Asia and the Far East. The case of India.

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1. Tractor industry in India

One of the most important changes, which have occurred in the south Asian sub continent, is the unprecedented growth of the agricultural economy. A look back at this century shows that generally the agricultural economy of India did not grow at all during the first half century from 1900 to 1950. The rate of growth of the agricultural economy between 1950 and 1970 was roughly 1% per annum.

The rate of growth of the agricultural economy rose in the 80s to about 2.5% per annum.

During the decade of 90s, the agricultural economy of India has grown at a rate approximating 4.5% per annum. [1]. This has economic, social and political ramification.

The per capita income in the agriculture sector also grew at a very high rate along with a moderate growth in the agricultural GDP (Gross Domestic Product) in India (**Fig. 1 and 2**).

The Indian agriculture scenario is handicapped with the following factors:

- small land holdings - while this varies from region to region, the average holding is about 2 hectares;
- relatively illiterate farmer, poor training, poor knowledge;

- poor infrastructure development in terms of road, storage facilities, transportation facilities, agricultural produce processing facilities (packaging, canning, rapid cooling etc.).

While during the socialist economy years from 1960 to 1990 the "Commanding Heights" of the industrial economy were possessed by the Government. On the other hand, the activity of agriculture in India has remained almost entirely in private hands. Producing industry such as steel, fertilisers, etc. the transportation industry such as railways, shipping, passenger road transportation, banking system, insurance system, was state owned.

The entire agricultural economy i.e. production of food grains, horticultural produce and cash crops such as oil seeds, sugar cane etc. remained entirely in private hands. The agricultural economy of India therefore was able to take advantage of changing technology in seeds, fertilisers and a liberalised, farmer friendly and supportive financial system, in spite of the handicaps mentioned above, such as small land holdings, illiterate farmer, and poor infrastructure. Due to improved irrigation methods and systems, the dependence on monsoon rains decreased. Three crops per year were possible in many parts of the country. Limited time for tillage/field preparation during and between crops made use of tractor power mandatory. Growing tractor population also changed the haulage scenario in the rural India. The bullock cart was replaced by the tractor.

On this background the tractor industry grew rapidly with the growth of the agricultural economy [2; 3; 4] (**Fig. 3**).

During 1960s Tractors were imported to India from renowned manufacturers the world over. During the 60s and 70s, local content was dramatically raised and the assemblers or importers graduated to tractor manufacturing capability. production in units per year, rose to about 45000 in 1977, 93000 in 1987 and 250000 in 1997 [4].

The spectacular growth of the agricultural economy and the stupendous developments in

the “tractorisation” of India are only the first step of the “modernisation of the agricultural economy” of India. Due to the all round economic development, based on the vastly improved rate of GDP growth in India during the 1990s (about 5.5% instead of the earlier 2.5% so called Hindu rate of growth), the nature of the Indian economy, Indian society and particularly the Agricultural scene, will further change during the coming decades. Increasing urbanisation and growth of service sector of the economy will make labour costs in the agricultural sector to rise.

While tractorisation in the 1980s and 1990s has replaced the bullock with the tractor, further developments are expected to result in increasing use of farm mechanisation and advanced agricultural implements and equipment such as threshers, rotavators, spraying systems and such.

A review of the tractor technology in India indicated that the range of tractors made in India during the 1980s and the early 1990s was not friendly to accept the modern farm mechanisation devices.

The tractor industry in India is characterised by the following:

- large volume of production; tractor sale in the year 1998-99 was 265,000 units.
- low horse power range.

The most popular power range of tractors is 35 HP. This along with 25 and 45 HP defines the bulk of the market (**Fig. 4**).

The tractor producers concentrated on volume growth in a rapidly growing agricultural Economy. product innovation, technology, modernisation, efficiency improvement aspects were not the drivers for the development and growth of the tractor industry due to low level of external competition and importantly also due to acceptance by the farmers of the simple but robust construction and functioning of the available tractors. Neither competition from more advanced manufacturers nor a demanding market place with a knowledgeable customer was present, to dictate or insist upon change or improvement in tractor technology. Consequently, the average tractor sold in In-

dia bears the design characteristics of the 1950s with:

- 5/1 to 6/2 gearboxes with low comfort sliding gear shift;
- poor ergonomics;
- generally outdated hydraulics;
- low safety consideration in terms of brakes, ROPS (not mandated).

2. The Tempo OX concept

2.1. The conception of Tempo OX tractor

On the above background, need for a technologically superior tractor was felt and the Tempo OX Tractor was conceived [5]. The firm Bajaj Tempo Limited had long established connections with German entrepreneurs, engineers and industry having established in the past, technical collaborations starting in 1950's with Vidal Sohn, for 3 wheelers, with Zahnradfabrik Friedrichshafen (ZF) for transmissions. Today the company has collaboration with Diamler Chrysler who participates in the capital upto 16%.

Dr. Rolf Bacher and Mr. Abhay Firodia are second generation shareholders in Bajaj Tempo, their fathers having established this firm in 1958. A project was conceived to design, develop, manufacture and market a new family of tractors for India using technical inputs from renowned industry, University and consulting resources from Germany. The study phase started during end 1992.

The tractor concept as evolved not only sought to overcome limitations of the Indian tractor industry in terms of technology of gear boxes, outdated hydraulics and poor ergonomics, but while improving the technology of transmission and hydraulics, with an eye to the future, it was decided to design the tractor to ‘build in’ easy upgradation possibility to 4x4 drive, and adaptability to modern farm mechanisation devices such as threshers, etc. The concept was evolved to build a tractor, which is right for India in terms power output,

but capable of efficiently utilising modern agricultural implements and methods.

Considerable strength on design, development, testing, production engineering and manufacturing is built-up by the firm Tempo during the last 4 decades. The technology level of this infrastructure is about the same as in high-developed countries.

Professor Renius, Head of the Department of Agricultural Machines at the University of Munich was consulted for:

- reviewing the concept of tractor suitable for India; market study and technical data was reviewed in details;
- finalising the selection of aggregates/systems;
- preparing the strategy for testing.

With the University, consultants and professionals involved from different countries, the tempo OX Tractor in that respect is truly a joint venture.

2.2. Customer expectations

While designing the OX tractor, following customer expectations were considered:

- improved power with high torque back up, for operating in different agro climatic conditions;
- efficient transmission and easy shifting of gears;
- higher capacity of hydraulics with sensitive response;
- good ergonomics;
- high reliability;
- less vibrations and noise;
- modern looks.

The above expectations were quantified to develop the OX tractor family concept. It was decided to start with the 45 HP tractor (**Fig. 5**).

3. Design and development of various aggregates. Technology transfer and major efforts [5]

3.1. Engine

The concept for OX family of tractors involved use of engines derived from the Mercedes OM 616 Diesel engine already industrialised by Tempo, to be converted to tractor application. i.e. from indirect to direct injection, further to be modified for the stiffness of block, crankshaft etc. and to be reengineered to deliver the necessary torque and horse power, suitable for tractor application. This work was carried out internally in Tempo with the active consultancy assistance from AVL List GmbH Graz, Austria. A modern tractor engine family was created to generate three engines, from the basic 2.4 Litre - 4 in line configuration:

- 45 HP from 2.6 Litre, 4 cylinders in line;
- 35 HP from 1.95 Litre, 3 cylinder in line;
- 60 HP from 3.25 Litre, 5 cylinder in line.

3.2. Transmission. Drive line

It was conceptualised to use a transmission design featuring many improvements such as synchromesh shifting, higher quality of gearing, driveline reliability [6]. The firm of ZF Passau, specialists in tractor transmission were contacted to provide design assistance and a family of axles suitable for tractors with horse power range of 25 HP to 65 HP are obtained under license.

Modifications were made to the transmission systems selected from M/s ZF Germany. The modifications were:

- ratios were altered to achieve desirable speeds;
- gears were strengthened for Indian usage load pattern;
- axle housing and axle shaft redesigned to suit "Wet Brake" configuration (**Fig. 6 and 7**).

The transmission for OX 45 contains 8 speeds forward, 4 speeds reverse and 2 shiftable speeds for the PTO.

3.3. Hydraulic powerlift

The ZF transmission was originally designed for using Bosch hydraulic valve with the ZF power lift block. Tempo decided to persevere with the excellent ZF hydraulic power lift and the Bosch control system. An agreement with M/s Bosch was realised to built up an adequate production system in India by Tempo. This was a very difficult procedure due to the required accuracy for hydraulic components, specifically valves.

3.4. Brake system

Wet Disc Brakes was an important features identified to be provided on the OX tractor. The safety and reliability was an important advance. Expectations of low pedal efforts and low noise were taken care of.

3.5. Front axle, weight distribution and stability

The required weight distribution was finalised considering the load with implement mounted on three-point linkage at the rear of the tractor. Full load and partial load conditions were taken into consideration.

Extensive finite element analysis (FEA) was done on these in the CAD environment in Tempo. In house designed front axle parts with different sizes and materials were evaluated to finalise.

3.6. Ergonomics

Seat layout was finalised in line with ISO requirements as shown in **Figure 8**. Bonnets and fenders were styled to be most modern and attractive (**Fig. 9**), a change from the 1950 styling of the Indian tractors. The CAD route on the comprehensive facilities did the design of tools for tool design & CNC manufacturing in Tempo.

4. Testing and analysis

Looking back, it was extremely helpful, to establish test facilities for the tractor components in a very early stage of the project. Elaborate design, analysis and testing plan as given below was followed:

- engine - FEA for structural parts, combustion studies for optimisation, performance and endurance tests and emission testing in laboratories of Tempo (**Fig. 10**). Finite element analysis of OX 45 front support bracket;
- transmission – the gear train, planetary gearing and differential gearing was evaluated for strength and life by detailed calculations. The transaxle was put on a closed loop axle test set up. The load cycle was finalised considering overloads based on field information. Statistical methods of forming load spectra helped to transfer fundamentals of West European transmission load analysis to specific Indian conditions;
- front axle and steering - FEA done to analyse for vertical load and drag load (**Fig. 11**);
- hydraulics - hydraulics were analysed in dynamic analysis software. Special test rigs were prepared for the pump endurance.
- Field-testing and certification was done after extensive in-house testing. Prototypes were submitted to Central Farm Machinery Training and Testing Institute (Budhni-M.P., India) for field-testing and certification.

5. Conclusions

Tempo started the training of service and sales staff during early stages of the project. These training programmes were most beneficial as more than 3000 OX Tractors have been produced after the series went into production in 1997. The customer acceptance and

successful use of the new technology systems in the OX Tractor were thus successfully managed. Initially the production was limited and progress was slow due to:

entire design being new, need to establish in-house manufacturing capacity, as also to stabilise the supplier base;

the company Tempo was new to the business of tractor manufacture;

almost the entire tooling in terms of patterns, jigs, fixtures dies gauging equipment was designed and manufactured in house in Tempo's own tool room. A massive effort of designing, manufacturing, debugging and putting into production a large variety of components using variety of manufacturing equipment involved enormous engineering inputs, cost and time. The same activity, if it had totally been entrusted to a European firm with a comparable infrastructure, the time would have possibly reduced by a factor of 30% but the cost would have increased by a factor of five. The Indo-European collaborative efforts helped reduce the project costs and time significantly.

The restricted volume of the first production phase was however helpful to limit the risks of such a completely new introduced, complex product. Feedback from the market, was in those cases of outstanding value, where the farmers used the tractors intensively – some more than 1500 hs in the first year itself. [7]. The authors of this paper visited several of them personally and they found a high level of driver motivation because of no major technical problems but surprising good handling and performance.

The resultant is that the OX range of tractors is fully indigenous and therefore will be in a “low cost manufacturing situation” from the very inception of production. The OX range of tractors while sporting a list of new technology innovations is comparable in price to the competing/ established Indian tractors – among which several models are two generations older in concept, design and performance.

What has been created is truly a modern tractor, comparable in performance and char-

acteristics to world market standards in its class. This has been achieved in a short time at a low investment. The introduction of the OX 45 has, along with liberalisation of the Indian economy and the declared plans of several global players to enter Indian market, stimulated desire on the part of the existing manufacturers also to improvise, innovate and generally modify their designs for the better.

Experience gained by the product designers including specialists in gear trains designers, hydraulic system designers, vehicle system designers, testing laboratories etc. in Tempo has been very considerable. The fall out of this effect is to create a large team of confident and experienced designers. A similar impact is felt on the development of process planning engineers, process tool designs, and on the fraternity of manufacturing engineers as a self-developed tractor project has proved a boost to the knowledge, experience and confidence.

The success of the OX 45 Tractor is gained from the synergy created between European technology houses and consultants such as University of Munich, Dr. Rolf Bacher, Prof. Renius, ZF Passau, AVL List GmbH, Bosch, etc. on one hand and the Indian engineers and manufacturers in the firm Bajaj Tempo, as also its suppliers, dealers etc. This tractor development project is distinguished by the fact that the co-operation between the Indian company and the European/German companies, consultants and University was based on professional and business considerations. The serious efforts on both sides ensure not only an interesting project but commercial success in future.

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Fig. 1 Per capita income in agriculture (Rs. per year)

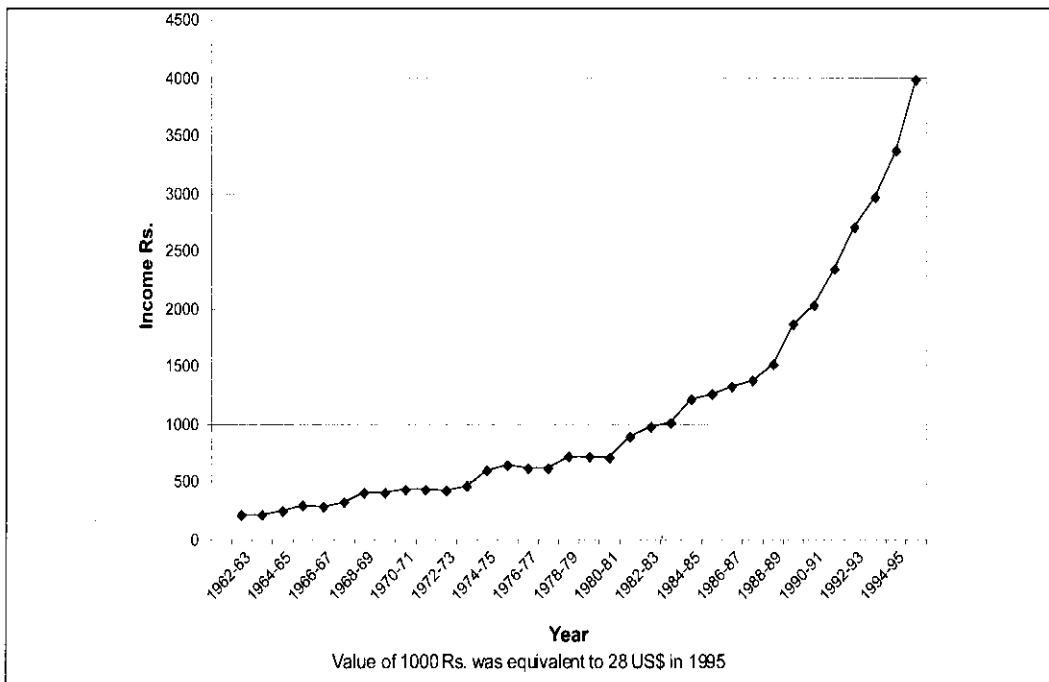


Fig. 2 - Agricultural GDP (rs. Crores)

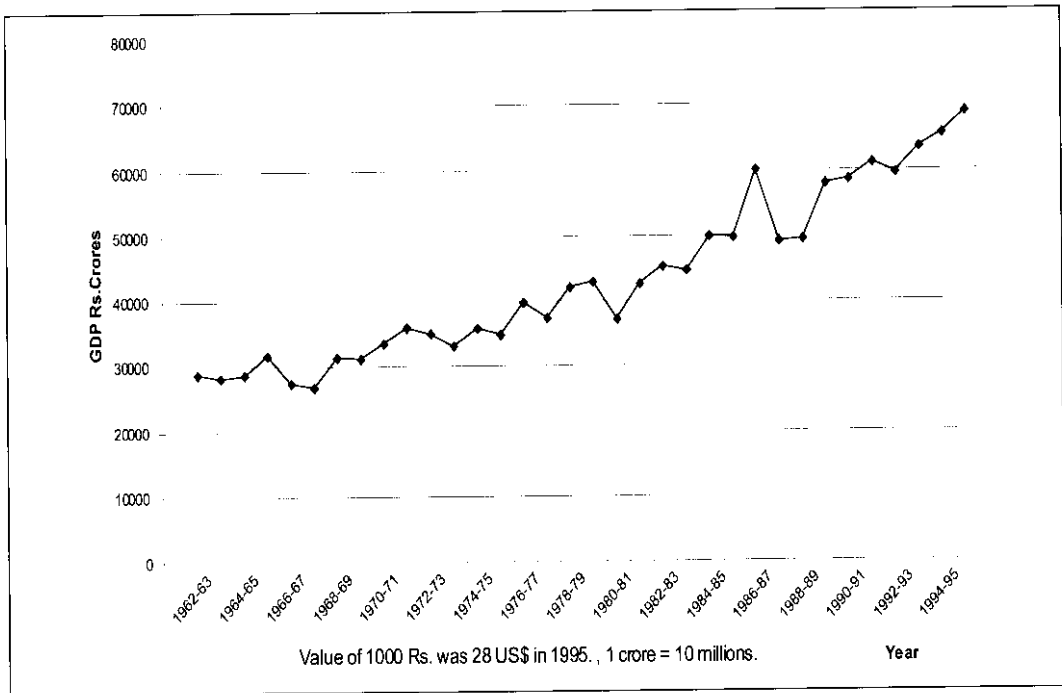


Fig. 3 - Tractor sale. Trend in last seven years

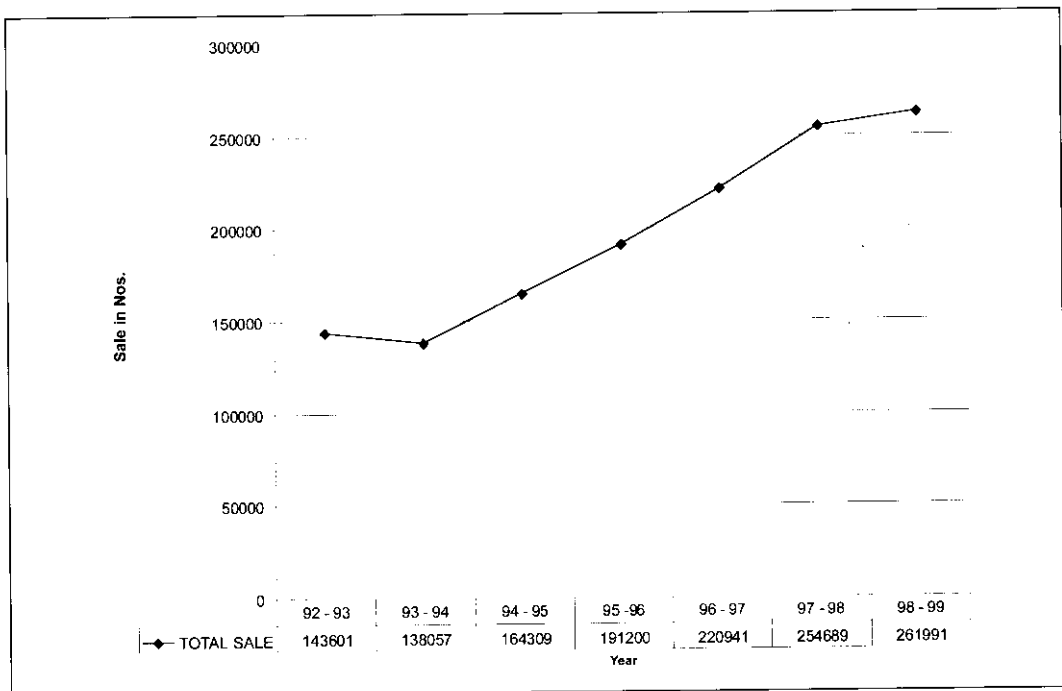


Fig. 4 - Segment wise tractor sale in numbers (1998-1999)

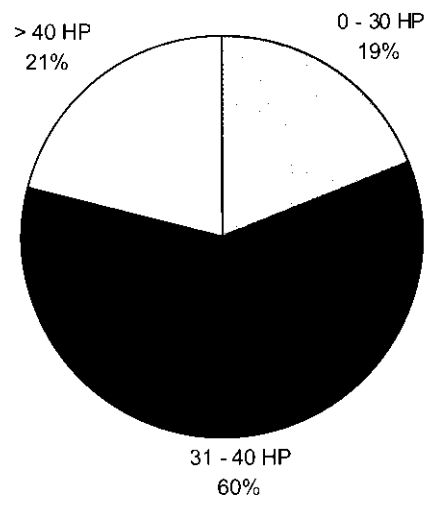


Fig. 5 - The OX 45 Tractor

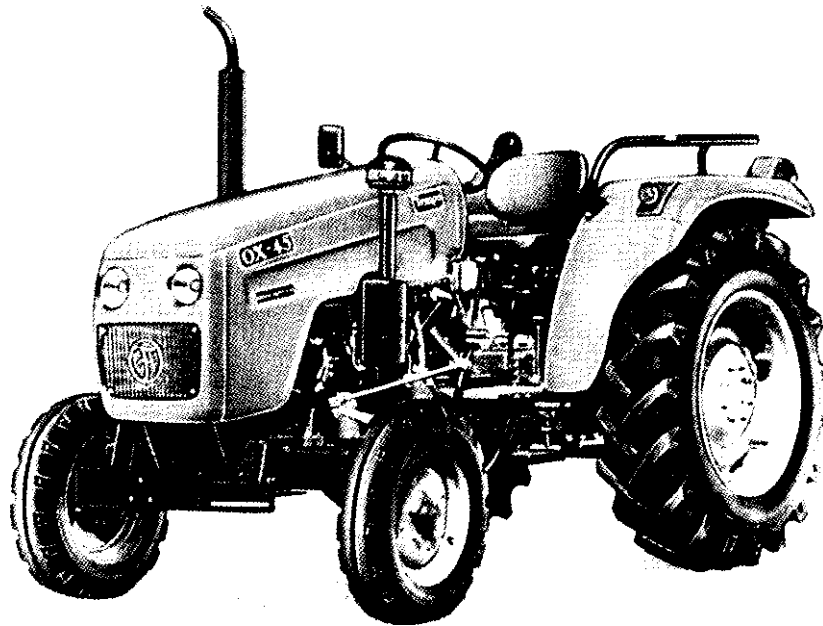


Fig. 6 - OX 45 transmission 12/4 with Syncromesh, 540/1000 PTO, Wet Brakes, planetary final drives and automatic three-point hitch control (Side view cross section)

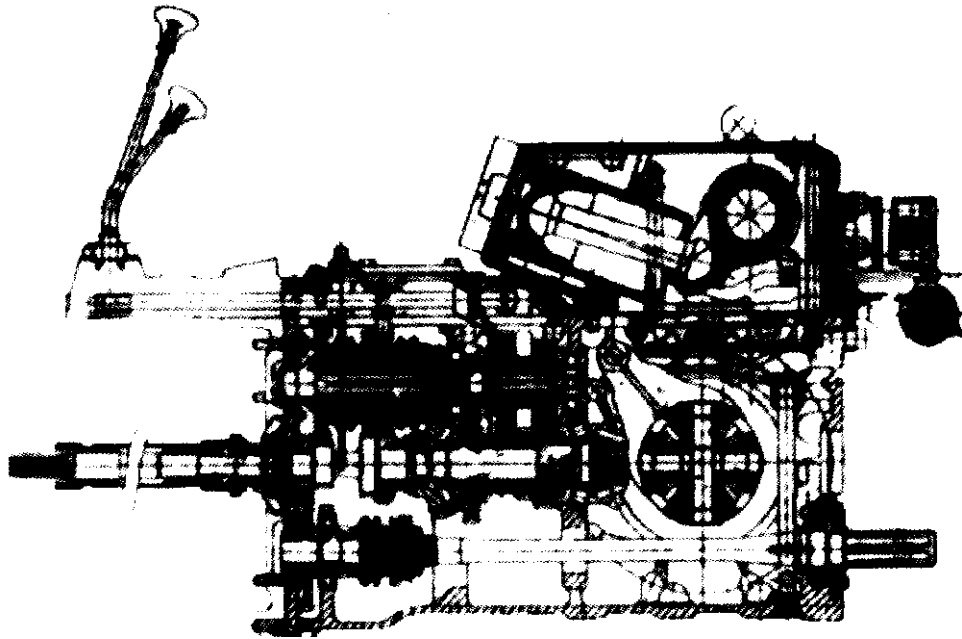


Fig. 7 - OX tractor TransAxle

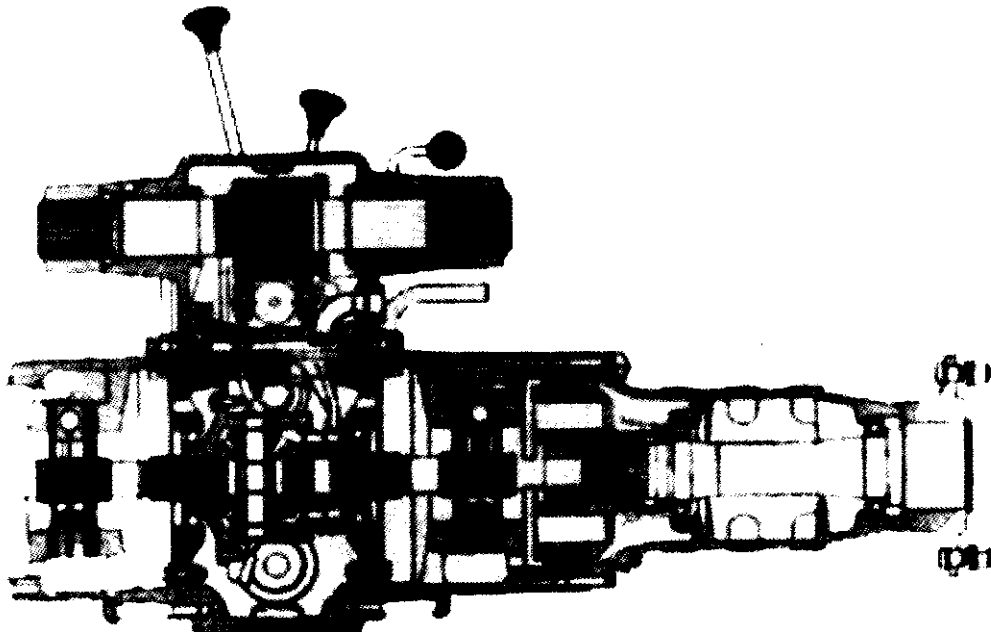


Fig. 8 - Tractor ergonomics

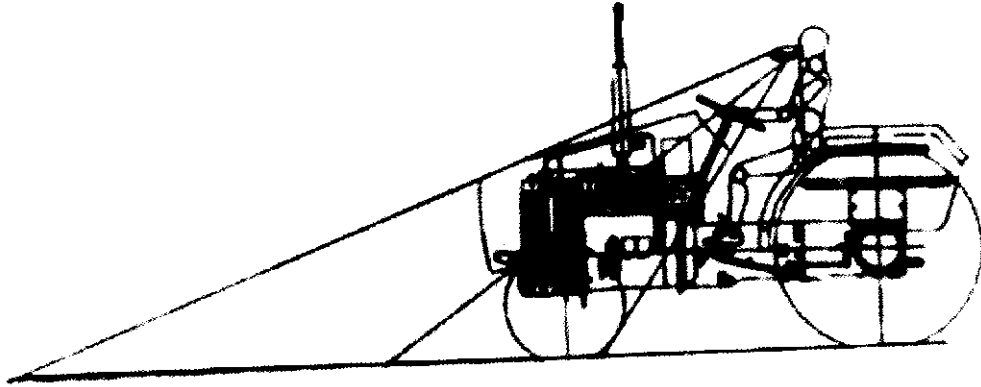


Fig. 9 - OX 45 bonnet and fenders

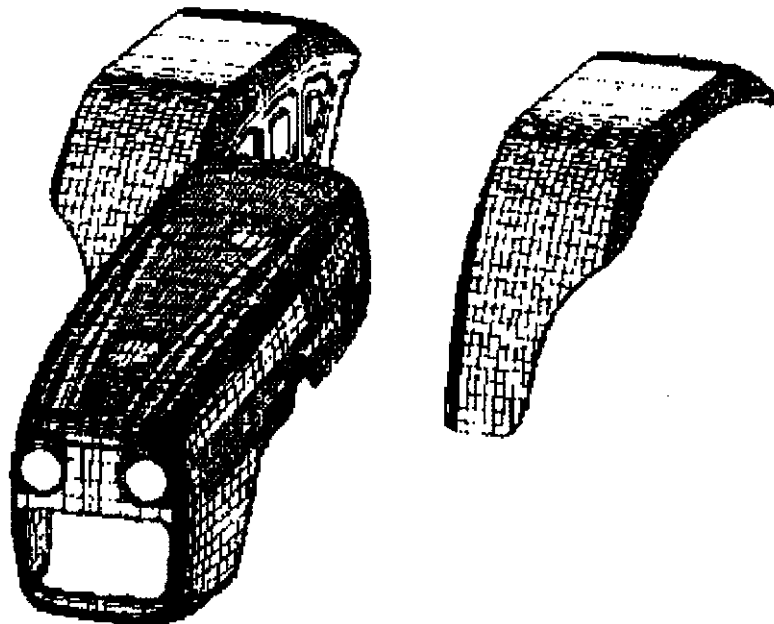


Fig. 10 - Finite element model of OX 45 front support bracket

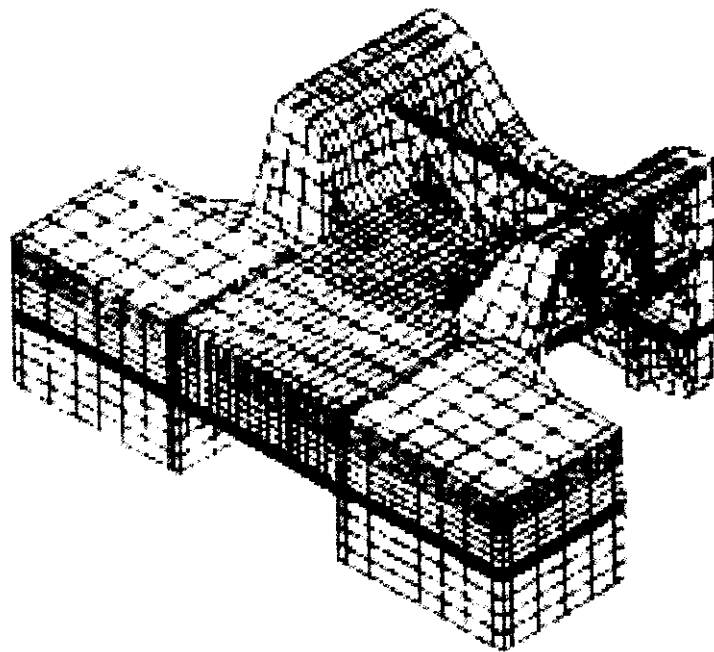


Fig. 11 - FEA of stub axle assembly

