Automotive Supply Chains and the Engineering Steel Supplier

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Introduction

Corus Engineering Steels (CES) produces approximately 1.5MTpa of engineering steel, over half of which is consumed by the automotive industry, through its associated supply chains.

Two of the most significant drivers in the automotive component sector are weight and through-cost reduction. Forged engineering steels face increasing challenges to their dominant role in the automotive engine, transmission and suspension sectors. Not only are alternative materials and competitive processing routes significant elements of that challenge, but so are the globalisation of the automotive industry and progressive rationalisation of component supply chains.

Steel suppliers, forgers and other supply chain players must therefore co-operate effectively if engineering steel components are to meet the automotive industry's through-cost, weight, durability, recyclability and other performance expectations.

This paper was presented at a conference 'Globalisation - A Metalforming Industry Response' organised by the Confederation of British Metalformers (CBM) 47 Birmingham Road, West Midlands in May 2000.

This paper illustrates how, through working closely with its supply chain, involving forgers, machinists and end users, CES has exploited its materials expertise and the component design expertise of Corus colleagues, to develop innovative and effective solutions to the automotive industry's evolving needs.

Fracture Split Connecting Rods - Development of FRACTIM® Grade

The successful development of fracture-splittable, forged steel connecting rods has enabled the forged steel product to regain from powder forgings the lowest through-cost position based on equivalent operational performance.

In fracture splitting, the big end cap is removed from the body of the connecting rod first by notching (usually by laser) and then by fracturing. The fracture splitting process offers major savings in the through-cost of connecting rod manufacture. A reduction of as much as 25% in plant investment costs and 35% in the processing costs of machining lines are claimed. [1]

The established grade for this forged steel application is known as C70S6. Similar to that developed by Ford, [2] it is now in regular use in Europe and the USA.

CES, working jointly with UEF at Kidderminster and Bromsgrove has developed an improved alternative to this steel grade, known as FRACTIM®, it offers further through-cost reductions, primarily by virtue of its improved machinability.

The future in metal

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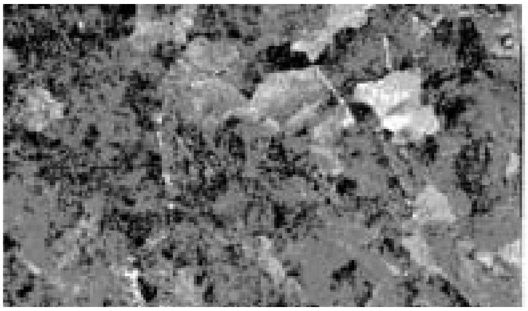
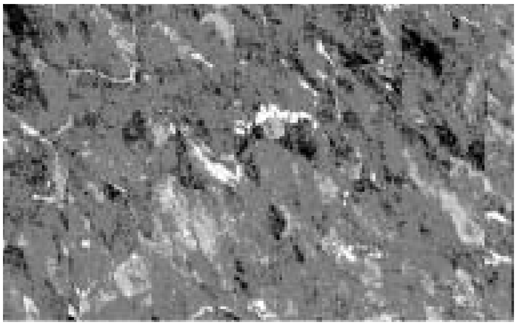
The chemical compositions and the tensile properties of FRACTIM® and C70S6 are shown in Table 1.

For minimum distortion of the big end on fracture splitting, it is important that the steel has a largely pearlitic microstructure. The use of a higher Mn level in FRACTIM® enables this to be achieved with a lower C content and a slight increase in the amount of ferrite compared with C70S6; see Figure 1.

Fig 1 Microstructures of C70S6 and FRACTIM®



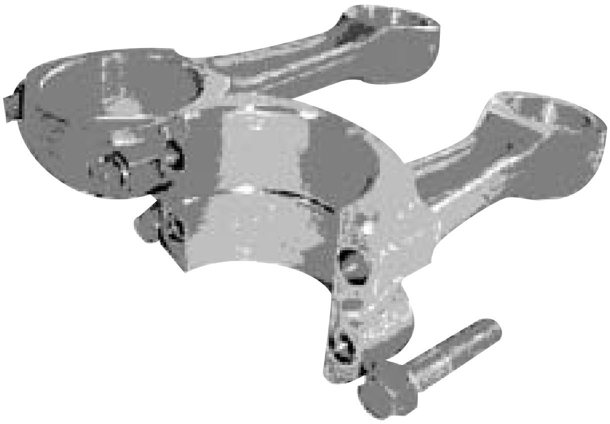
C70S6
x200



FRACTIM®
x200

In order to achieve the low ductility required for fracture splitting, the phosphorus level in FRACTIM® rods is always close to the top of the 0.045 wt % maximum allowed in the specification. As illustrated in Figure 2, fracture split connecting rods made from FRACTIM® exhibit good fracture surfaces and minimum distortion.

Fig 2 Fracture Split Connecting Rods in FRACTIM®



The use of a high Mn level in FRACTIM® enables a higher sulphur level to be employed than is the case for C70S6. This, in conjunction with a lower level of carbides in the microstructure, achieves a significant improvement in machinability over the established C70S6 grade.

Table 1 Typical Composition Ranges and Strength Levels - C70S6 and FRACTIM®

	C (wt %)	Si (wt %)	Mn (wt %)	P (wt %)	S (wt %)	0.2%PS (N/mm²)	UTS (N/mm²)	El %	R/A %
C70S6	0.68/0.75	0.15/0.35	0.50/0.60	0.045 max	0.060/.070	580	1000	12	15
FRACTIM®	0.55/0.65	0.15/0.35	0.60/0.90	0.045 max	0.080/.100	600	1000	18	18

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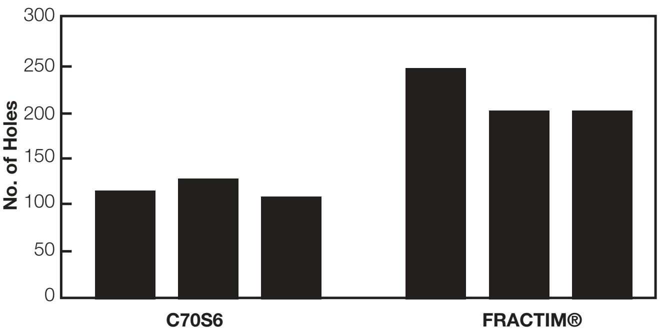
Drilling and tapping of the boltholes is a critical aspect of the machining of connecting rods. A back- to-back comparison of C70S6 and FRACTIM®, carried out by the University of Aston, has shown a doubling of HSS drill and tap life when FRACTIM® is used. This is shown in Figures 3(a) and 3(b), along with the details of the conditions employed.

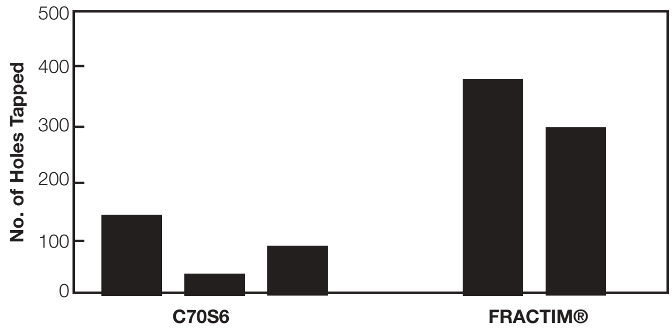
Fig 3a Drilling Tests on C70S6 and FRACTIM®



Test Conditions

Condition	Setting
Size of Test Strip	37mm x 18mm x 300mm
Depth of Hole Drilled	18mm Blind
Heat Treatment	1150°C and Air Cool
Hardness - C70S6	280 HV30
- FRACTIM®	280 HV30
Drill	HSS
Coating	TiN
Size	6.35mm Dia.
Speed	1890rpm
Feed	0.25mm/rev
Coolant	5% Chlorine Free Coolant

Fig 3b Tapping Tests on C70S6 and FRACTIM®



Test Conditions

Condition	Setting
Size of Test Strip	37mm x 18mm x 300mm
Depth of Hole Drilled	18mm through hole
Heat Treatment	1150°C and Air Cool
Hardness - C70S6	280 HV30
- FRACTIM®	280 HV30
Drill	6.8mm dia Kennametal TiN coated carbide stub drill
Tap	TiN
Speed	12.5/min (500rpm)
Feed	625m/min
Coolant	Houghten Vaughan TypeB 300S 5% concentration

The benefits arising from the use of FRACTIM® have been realised on production machining lines.

All other performance characteristics of FRACTIM®, including those deriving from laboratory and engine fatigue testing have shown the performance of FRACTIM® to be equal to or better than that of C70S6.

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A higher strength version of the successful FRACTIM® grade is now under development.

The Use of Lower Cost Carburising Steels

The choice of steel grade for carburised components such as gears, has a significant effect upon downstream processing costs and sensitively influences other issues such as heat treatment distortion. [3] This has undoubtedly accounted for reluctance on the part of some automotive supply chains to change from well-established Ni-based grades for these applications. However, recent increases in the price of nickel are forcing a re-appraisal of this situation.

Two examples of how CES has assisted in reducing through-costs now follow.

The first example involves the development of a MnCr grade to replace a high hardenability 21NiCrMoS5 grade where no direct substitute previously existed.

The second concerns the direct substitution of a proprietary 21MnCrMo4 type, for a 8620 type NiCrMo steel.

The Use of MnCr Type in Place of a High Hardenability NiCrMo (21NiCrMoS5) Grade

The end user requires a deep-hardening, carburising steel and currently uses a 21NiCrMoS5 type with relatively high hardenability. There was no readily-available, lower through cost grade which could substitute, as the hardenability required is higher than that achievable using the conventional 20MnCr5 range.

CES carried out initial development work on small-scale, laboratory melts to show that the use of higher C, and Cr levels could enable the required hardenability to be obtained with a MnCr type grade.

Using data from the laboratory melts, a prototype, commercial-scale cast was produced to the composition shown in Table 2.

Table 2 Composition Ranges of 21NiCrMoS5 and 21MnCr5 Grades

	C (wt %)	Si (wt %)	Mn (wt %)	S (wt %)	Cr (wt %)	Mo (wt %)	Ni (wt %)
Existing 21NiCrMoS5 Range	0.18/0.23	0.15 max	0.90/1.20	0.040/0.050	0.90/1.20	0.12/0.17	0.90/1.20
Standard 20MnCr5 Range	0.17/0.22	0.15/0.40	1.10/1.40	0.025/0.035	1.00/1.30	-	-
Modified 21CrMnS5 Range	0.19/0.23	0.15 max	1.25/1.40	0.040/0.050	1.25/1.40	0.10 max	0.25 max
Commercial Cast	0.22	0.13	1.35	0.046	1.35	0.07	0.10

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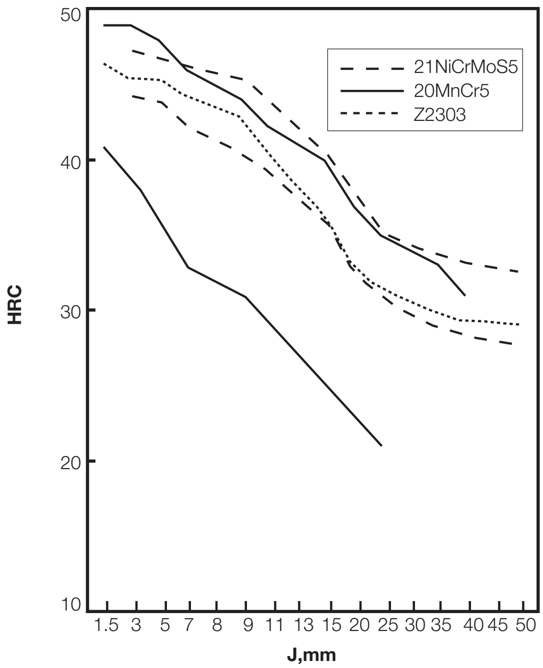
The hardenability bands corresponding to the 21NiCrMoS5 grade, the standard 20MnCr5 grade, and to the 21CrMnS5 commercial-scale development cast are shown in Figure 4. It can be seen that the latter met the 21NiCrMoS5 requirement.

Prototype forgings were produced by three forgers, in close collaboration with CES who also provided assistance with modified annealing heat treatments. CES worked closely with the end user throughout. Gear and shaft components have been manufactured and have proven to be satisfactory in terms of case and core properties, and of distortion behaviour. Approval to change to the new grade is expected shortly.

Use of the new grade will result in a reduction in current through-costs of up to 17%.

Figure 4 Hardenability Bands of Existing 21NiCrMoS5 Higher Hardenability, Standard 20MnCr5 Grades and Result for Cast Z2303



The Use of a 21MnCrMo4 Type in Place of a NiCrMo (SAE8620) Grade

The end user had available a proprietary 21MnCrMo4 type steel which could be substituted for an SAE8620 type. The composition of both grades is as follows:-

Table 3 Composition Ranges of NiCrMo (8620) and 21MnCrMo4 Grade

	C	Si	Mn	Cr	Mo	Ni
SAE8620	0.18/0.23	0.15/0.35	0.70/0.90	0.40/0.60	0.15/0.25	0.40/0.70
21MnCrMo4	0.20/0.25	0.15/0.35	0.90/1.20	0.40/0.60	0.13/0.20	0.3 max

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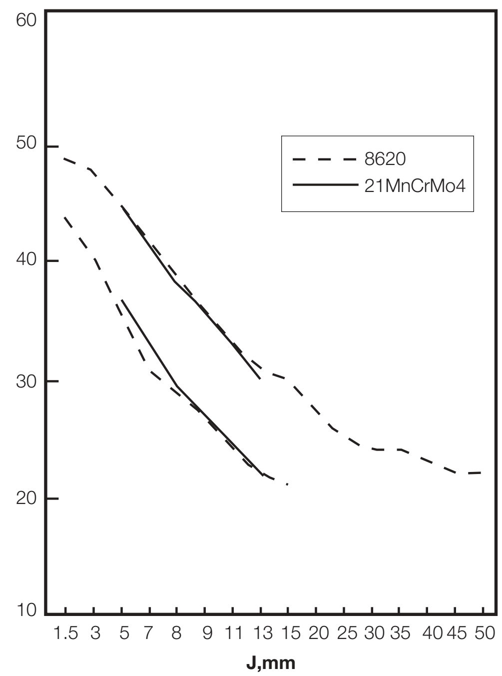
The hardenability ranges of the two steels are shown in Figure 5, where it can be seen that the 21MnCrMo4 grade displays a slightly higher hardenability.

CES supplies approx. 8KTpa of this steel to three UK forgers and began changing to the new grade at the beginning of 2000, following initial trials. Close contact was maintained with the forgers and the end user throughout the changeover to ensure that a smooth transition took place.

To date, 6 casts, equivalent to 720 tonnes have now been supplied, with a current, through-cost reduction of up to 10%.

Figure 5 Hardenability Bands of the 8620 and 21MnCrMo4 Grades



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Optimisation of Component Design and Manufacture - Knuckle and Suspension Arm Components

In the continuing quest for cost and weight reduction, engineering steel automotive forgings compete fiercely with alternative materials such as cast iron and aluminium. This is particularly true in the field of automotive chassis components.

It has been demonstrated that by optimising engineering design, materials and manufacturing route, it is possible for engineering steels to meet this competition.[4]

The materials expertise of CES, and the engineering design and analysis (CAD and CAE) expertise of Corus Automotive Engineering were applied to the optimisation of the knuckle and suspension arm components shown in Figures 6 and 7.[5] Two UK forgers were involved in the exercise.

It was shown that a reduction in weight of 29% could be achieved for the original cast iron knuckle and 24% for the forged steel suspension arm. By selecting air cooled steels, it was also possible to minimise manufacturing process costs.

Fully to exploit such optimisation, all members of the supply chain work together at the early stages of development; however, it is imperative that Early Vendor involvement (EVI) is vital.

Figure 6 Current and Proposed Knuckle Design

Current Cast Iron Component

Proposed Forged Steel Design

Figure 7 Current and Proposed Designs for Suspension Arm

Current Design

Proposed Design

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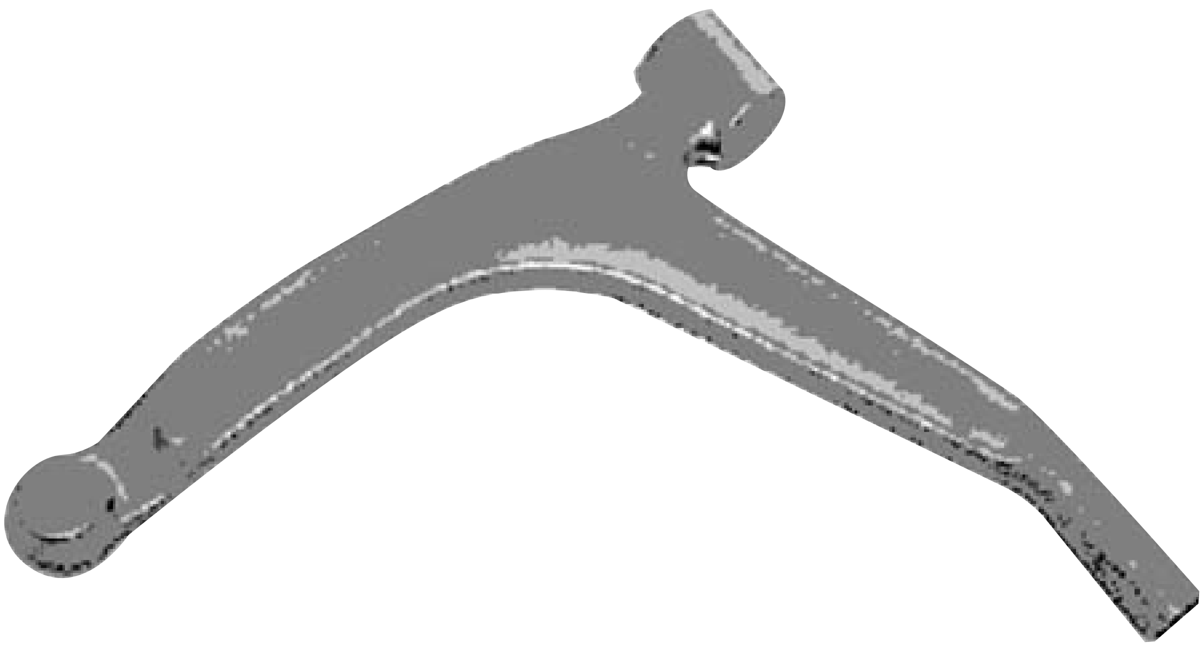
The Manufacture of an Air Cooled Suspension Arm Forging

CES worked closely with a forger, (T.B. Wellings Ltd.), in the development of a manufacturing route for a forged steel suspension arm for a multi-purpose vehicle. The forging, which is shown in Figure 8, had previously been produced by an off-shore forging competitor using a press, whereas CES' collaborator employed hammer forging.

The end-user specification required a fine grain size and a minimum impact value of 40 J/cm^2 KCU. Most air cooled forgings have a coarse grain size and struggle to achieve these impact values. [6]

Figure 8 Front Suspension Arm Forging



The steel specification was 30MnSV6 which is a .30wt%C microalloyed steel with an addition of titanium. The use of Ti refines the grain size by forming grain boundary-pinning Ti(CN) precipitates during forging. This means that if the finish forging temperature is sufficiently low, a fine grain size can be attained in the final forging. The 30MnSV6 grade was not in regular manufacture at CES at the start of this work and initial trials were carried out on other air cooled steels, with and without Ti additions, to ensure that the end-user specification was attainable.

CES collaborated closely with Its customer and conducted several joint trials to establish the forging route. (In so doing it was shown that steels without a Ti addition could not achieve the fine grain size required, regardless of forging conditions).

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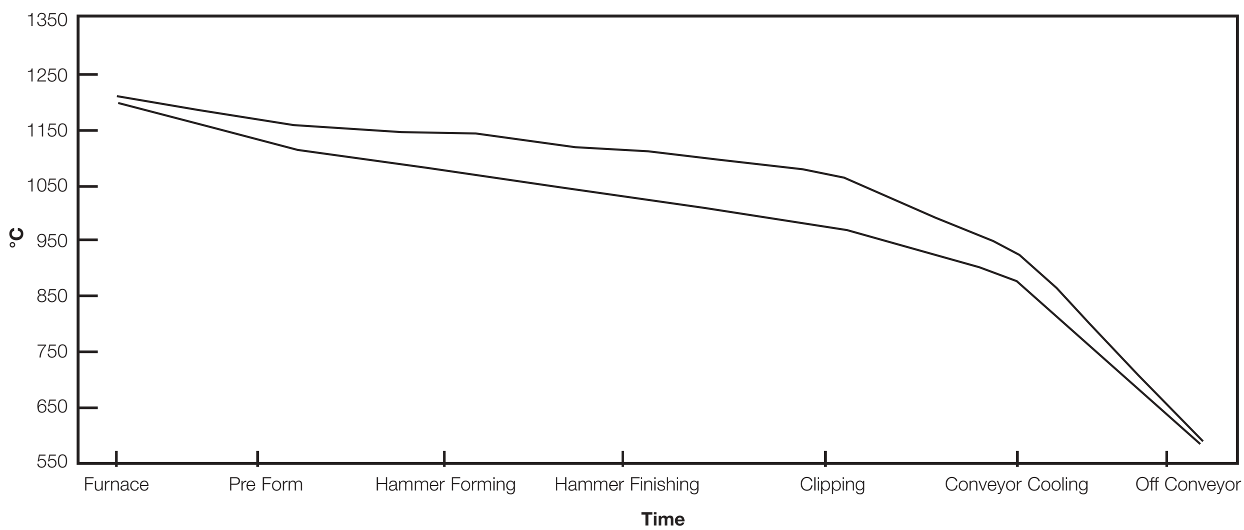
The temperature / time profile chosen for the forging route is shown in Figure 9.

Figure 9 Temperature/Time Profile for Forging Operations



The prototypes were approved by the end user and since the initial trials at the end of 1999, a total of 85,000 forgings and 5 casts, equivalent to 600 tonnes of steel, have so far been successfully supplied for this application.

Details of the first cast supplied and the properties achieved in the first prototype forgings were as follows:

Again this demonstrates the benefits that accrue from supply chain collaboration.

Table 4 Composition of Prototype Forgings

	C (wt %)	Si (wt %)	Mn (wt %)	P (wt %)	S (wt %)	Al (wt %)	Ti (wt %)	V (wt %)
Commercial Cast	0.31	0.63	1.54	0.007	0.072	0.031	0.025	0.11
30MnSV6 Specification	0.30/0.33	0.50/0.70	1.40/1.60	0.025 max	0.065/0.090	0.015/0.040	0.010/0.025	0.08/0.14

Table 5 Properties of Prototype Forgings

	Grain Size ASTM	Hardness Hv	Impact Value J/cm^2 KCU
Actual properties	7-8	266-274	48/60
Specified properties	5 min	253-301	40

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ULSAS (Ultra-Light Steel Automotive Suspension)

CES is one of a group of 34 steel producers from 11 countries who are members of the ULSAS consortium, the activities of which are co-ordinated by the International Iron and Steel Institute (IISI). The first published report by the ULSAS Consortium [7] was the culmination of a benchmarking exercise which compared four major car suspension systems deemed to be the most significant, and with potential for further improvement. The second phase of the programme involves steel-intensive solutions for cost and weight reduction. Publication of the report on this phase is imminent.

Value Stream Mapping

One of the tools of "Lean Management" is Value Stream Mapping and involves analysis of the entire supply chain in order to add value and reduce waste. The elimination of waste is the primary goal.

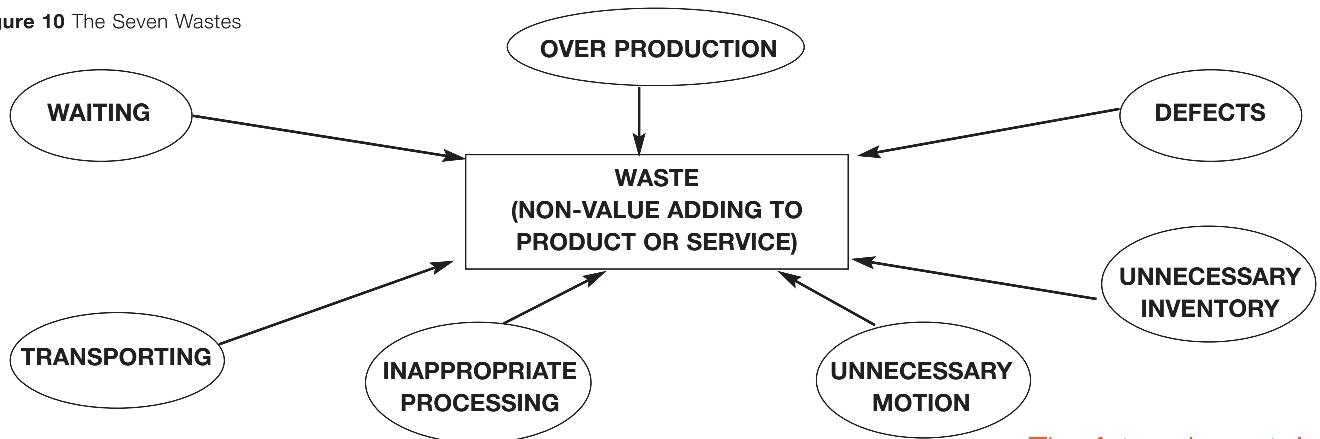
A major European vehicle manufacturer, with whom CES had a historical technical and commercial relationship had been carrying out benchmarking from Its own global activities. This revealed that it was possible to purchase gearbox forgings from India and the Far East at 40% lower in cost than in Europe. Such a large reduction threatened not only the supply base, but also the vehicle manufacturer's own assembly activity.

Both CES and the vehicle manufacturer were familiar with working with the Cardiff Business School Lean Enterprise Research Centre and it was decided to apply Lean Manufacturing techniques to these products and process routes.

CES, in conjunction with two leading European forgers and the vehicle manufacturer, took part in the Value Stream Mapping of three gear component supply chains [8]. The aim was to reduce the through cost of these components by 25%. Some of this cost would be achieved by substituting a leaner alloy steel, as described earlier.

The Teams identified waste in the seven generic areas shown in Figure 10.

Figure 10 The Seven Wastes



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One element of the study involved order fulfilment at CES. It revealed that handling an order involved 18 different activities over a period of 5 days, as shown in Figure 11. As a consequence, the ordering and receipt activities were changed by CES and by its customer to eliminate duplication and vetting. By so doing the handling period was reduced to one day. This is one, small example of the full supply chain activity which is continuing and, to-date, has already identified through-cost reduction opportunities of 22%.

Figure 11 Study of Order Receipt and Entry Process

PROCESS ACTIVITY MAP

Process Activity: Order receipt and entry

No.	Step	Flow	Area	Dist Mts	Time min	People	Comment
	Fax received from customer						Every day - at random. A mixture of orders and amendments
1	Delay for picking up fax	d	Sales office	0	30	1	-
2	Pick up fax	t	Sales office	5	0	1	Fax if right next to the desk
3	Check contents of fax	i	Sales office	0	1	0	Validating delivery information
4	Delay for batch	d	Sales office	0	8	0	Filtering for cancellations and amendments
5	If not urgent file away	t	Sales office	5	1	1	Waiting for the original to arrive
6	If urgent, process fax	o	Sales office	0	1	1	Gets roll week and delivery week information. One in 10 orders urgent
7	Find steel	o	Sales office	0	5	1	One in 10 orders. Standard product
8	Wait for original order to arrive	d	Sales office	0	2880	1	Can be up to four days
9	Check pile of faxes against the originals	i	Sales office	0	15	1	To ensure that they tie up OK
10	Deal with orders which don't tie up	d	Sales office	0	5	1	Due to faulty fax m/c or already issued
11	Get roll numbers and weeks	o	Sales office	0	5	1	Delivery dates etc.
12	Delay for batch	d	Sales office	0	55	1	Various orders from other customers
13	Type order onto the system	t	Sales office	0	2	1	If customers don't use part numbers time wasted
14	Delay for batch	d	Sales office	0	58	1	Batch of orders
15	File in logging basket	t	Sales office	10	2	1	For matching department
16	Expedite order	o	Sales office	50	2	1	Happens once every fortnight
17	Amend orders	d	Sales office	0	90	1	Cancellations, deferrals reductions
			Totals	**70 metres**	**3160 mins**	**15 people**	

Notes

Key Points:
Communication delays are significant; high level of amendments

Causes:
Working Practice - need for original to arrive.
Inaccurate forecast info

Effects
Information delays are significant; high level of amendments

Comments:
No standard procedures for order entry
Fixed lead times used to determine delivery dates

Opportunities:
EDI communication of requirements
Reviewed and standardise order entry working practices
Develop planning model to improve accuracy of delivery promises
Plan closer to actual requirement date - pull system

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Conclusions

The continued use of steel forgings by the automotive industry will depend upon the ability of the full supply chain to meet ever more demanding through-cost and weight reduction targets.

The examples given in this paper show that CES continues to leverage Its technical and business management skills with its customers and the end users to achieve effective solutions.

In order to succeed, it is imperative that members of the supply chain work closely together using Lean Management techniques to drive out waste and leverage their individual and collective strengths to exploit technology for highly competitive routes to market.

As globalisation of supply chains intensifies, CES and Its Corus Group colleagues will ensure that the expertise is exploited in collaboration with winning partners.

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