

LASER nytt

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VOLVO driver Laserutvecklingen

Den traditionella Laserdagen på väerkanten hölls i år hos Volvo Personvagnar, Torslandaverken i Göteborg där Johnny K. Larsson med kollegor hade ställt samman ett trevligt program tillsammans med IVF.

Dagen hade också ett internationellt inslag med ett inledande föredrag av Peter Grollman, Fisba Optik AG, Schweiz som berättade om svetsning av plaster, se separat artikel. Totalt var vi 52 deltagare som fick uppleva en intressant och trevlig Laserdag.



*Föredragshållare vid Laserdagen hos Volvo Personvagnar i Göteborg.
Fr v Urban Todal, Niclas Palmqvist, båda Volvo Personvagnar, Ulf Sandström, Permannova Lasersystem, Thomas Nilsson, IVF, Johnny K. Larsson, Volvo Personvagnar, Conny Lampa, IVF, Bernt von Brömssen, IVF samt Peter Grollmann, Fisba Optik.*

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Bernt von Brömssen, IVF, presenterade ett föredrag "State-of-the-Art" för laserskärning där han gav en översikt över metoden, från historik till framtida utveckling. Han visade bl a kostnaden för laserskärning är 1,4 till 1,7 gånger högre än för gasskärning med fyra brännare respektive finstråleplasmaskärning. Uppgifterna gäller för stål 8 mm tjocklek, 5 års avskrivning med 3200 timmar och en 3 kW CO₂-laser utrustning samt 50% skärbägsfaktor. I 15 mm stål med samma förhållanden blir laserskärcostnaden 2,6 gånger högre jämfört med gasskärning också det med fyra brännare. Det är kapitalkostnaden som fördyrar laserskärningen. Driftskostnaden ligger på i princip samma nivå för de olika metoderna.

Bland framtida trender inom området berättade Bernt bl a att prestanda avseende produktivitet (skärhastighet) och kvalitet kommer, att marknadsandelen ökar och att investeringskostnaderna minskar samtidigt som mera komplexa laserskärmaskiner som inkluderar svetsning, härdning, cladding och märkning är att vänta. Det har nu demonstrerats laserskärning av 10 mm hål i 1 mm tjockt stål med 500 hål/min. Vidare så kommer adaptiv skärning genom övervakning, skärning med dubbelfokus, diffraktiv optik med andra former på strålarna. Automatiseringsgraden förväntas också öka genom t ex laddning och plundring helautomatiskt även i tjocka metaller, separat CNC-styrd plockmaskin som plundrar skärbordet. Kanske slår även laserskärning för hand också igenom. Skärning med diodlaser med fiberöverföring av strålen som kan ge skärhastigheter på 2 m/min vid 500W lasereffekt i 2 mm konstruktionsstål. Laserutvecklingen fortsätter ju också med t ex diodpumpad Nd:YAG-laser som nu finns i multi-kW området.

Dr Conny Lampa, IVF, berättade om LASIM, ett datorprogram som kan användas i utbildning inom laserteknik. Programmet ger t ex möjlighet att träna procedurer vid hand-

havande av lasrar samt visar exempel på hur olika parametrar påverkar resultatet vid svetsning av olika material. Programmet är utvecklat vid Fraunhofer-institutet i Aachen och kan köpas därifrån.

Johnny K. Larsson, Volvo Personvagnar, Göteborg höll en intressant och välillustrerat presentation om historik och utvecklingstrender för laserbearbetning inom bilindustrin samt "den sanna historien om utveckling, konstruktion och flexibel tillverkning av en lyxbilskaross - S80".

Det moderna karossbyggandet inom bilindustrin ställer krav på styvhet, livslängd och hållfasthet vilket ska åstadkommas genom val av rätt material, form (konstruktion) och sammanfogningsmetoder. Speciellt för kupén är styvheten en viktig egenskap, vilken har ett avgörande inflytande på bl a vägegenskaperna. Inom karossbyggandet idag används många olika materialtyper som kolstål, olika grader av höghållfaststål, aluminium, plast, sandwichmaterial och magnesium. Detta ställer också krav på olika mer eller mindre nya sammanfogningsmetoder som limning, clinchning, och nitning. Tabell 1 visar hur användandet av höghållfaststål successivt har ökat inom Volvos produktprogram. EnS80-kaross består av 350 olika pressade plåt detaljer.

För att foga samman en S80-kaross används 4308 punktsvetsar och 2430 mm lasersvetsning samt en del bägsvetsning. Huv och baklucka tillverkas i aluminium och för att foga förstärkningar av stål och aluminium till innerstrukturen som består av aluminium så används 20 clinchningar till huven och 36 till bakluckan. För-

stärkningar till läset i bakluckan sätts fast med 7 självborrande nitar. Limning används också i tillverkningen av dessa detaljer.

I produktion i Torslanda karosfabrik används ett pallettsystem som gör det möjligt att tillverka flera modeller och varianter i samma tillverkningsline. Systemet bygger på att detaljerna, vars geometriska spridning ska vara $\leq 0,2$ mm, spänns fast i palletterna som är av tre typer, golv, sidor och tvärsektioner. När alla detaljer är monterade och fixerade i palletterna (tolerans $\leq 0,5$ mm) sammanstrålar palettbanorna och golv, sidor och tvärsektioner fogas samman. Toleransen för karossen i detta tillstånd är $\leq 0,7$ mm. Efteråt läggs taket på och karossen färdigsvetsas.

I nästa generation karosser kommer hydroformade ramdetaljer avslutar Johnny Larsson.

Nicklas Palmqvist, Volvo Personvagnar, Göteborg berättade kort om lasersvetscellen på Torslandaverken som svetsar fast taket på S80 och nya V70-modellerna. Den var från början utrustad med en 6 kW CO₂-laser med optisk arm och industrirobot, men för att öka produktiviteten installerades 1997 ytterligare en 6 kW CO₂-laser med optisk arm och industrirobot. Cykeltiden är nu 65 sekunder.

Permanova Lasersystem AB, Mölndal har installerat en Nd:YAG-laserskärcell på Torslandaverken berättar **Ulf Sandström**, som ansvarar för systemutveckling och leveranser vid företaget. Systemet utför skärning av varianthål i nya Volvo V70 Cross-country för infästning av skärmbred-

Tabell 1. Användning av höghållfast stål i olika Volvo modeller.

Bilmodell	Karossvikt (kg)	Mängd höghållfaststål (%)
240	345	0
740	330	20
940/S90	361	20
850/S70	354	40
S80	360	45

dare. Dessutom utför den skärning i referensplåtar även i andra modeller som sitter insvetsade i karossen, men plåten skärs inte helt lös utan man lämnar 1 mm brygga så att plåten enkelt kan brytas lös vid en senare operation.

Skärningen av varianthålen, som är 7 mm i diameter utförs i A-fabriken. Fördelarna med tekniken enligt Ulf Sandström är att man slipper deformation av ytterplåten och att man endast får en liten påverkan på en innerplåt som sitter på ca 10 mm avstånd. Man har också löst problemet att förhindra att skrotbitar hamnar inne i karossen.

Lasertekniken utvärderades naturligtvis mot andra tekniker och då fann man att konventionell borrning inte höll måttet. Visserligen är investeringskostnaden låg men man får spår i karossen och deformationer samtidigt som livscykelkostnaden är hög. Plasma skärningen klarade inte håltoleransen på ± 0.2 mm samt påverkade innerplåten negativt.

Så lösningen blev en pulsad 500 W Nd:YAG-laser med två ABB robotar som uppges ha så god precision (ca ± 0.1 mm enligt ABB) att man inte behöver ha några extra axlar (xy-bord) i robothanden. Systemet är också utrustat med vacuumsugning av skrotbrickorna samt ett fällbart munstycke för maximal åtkomlighet. Man räknar skrotbrickorna och fattas en så stannar systemet. Vidare så har varje station sk TCP-kontroll för att bestämma fokallägets orientering i rymden. Skärhuvudet har vidare ledad kollimeringsoptik för att öka åtkomligheten och för att minska kabelslitage.

Ulf Sandström berättar att erfarenheterna efter skärning i 90 000 karosser är mycket goda. Men man har fått göra vissa ändringar i munstycksutformningen på grund av störningar från skärsprut och karosserikitt som fastnade på munstycket.

Laserdagen avslutades med en intressant rundvandring i karosserifabriken där vi fick se både svets- och skärcellen i arbete.



52 deltagare hade mött upp vid Laserdagen den 18 maj 2000 hos Volvo Personvagnar i Göteborg där vi fick ta del av ett intressant program och bl a se karosserifabriken med lasersvets- och den nya laserskärcellen i produktion.

Flexible welding of plastics in industrial applications

Av Peter Grollman, Fisba Optik AG

Lower costs and sophisticated technology have made high-performance diode lasers ideal tools for use in industrial applications. The welding of plastic materials is a particular area where they enjoy ever greater popularity. This new method of fitting components together offers many benefits. Notable among them are strong seams, flexibility in use, and the possibility they offer of combining different plastics with one another.

Trendsetting welding technology

High-performance diode lasers are a relatively young technology. A longer lifecycle - 10'000 operating hours are now considered normal - and lower purchasing costs are major reasons for their growing acceptance in industrial applications. For its latest generation of high-performance diode lasers, the Swiss technology firm FISBA OPTIK AG has developed special micro-optics. These feature high operating efficiency and superb beam quality, both essential prerequisites for low-cost welded seams and spot welding at minimum thermal expansion. They achieve

spot welds of less than 0.5 mm in diameter. Their compact design makes these high-performance diode lasers the ideal tools for use in processing machines and in automated processes.

From radiation source to laser tool

Besides the radiation source itself, FISBA offers a range of optional accessories essential for industrial use. Because the laser beam is in the infrared range, a red pilot laser is coupled to it and forms a visible dot at

the laser's focal point. A built-in video camera can display the area around the focal point, for example on a monitor, for visual control of the process, and the outstanding image quality permits analysis on an image-processing system. An output meter can also be fitted in the laser head for use when the laser is used at high load and it is essential that the beam be monitored without a break in operation.

Process temperature is the most important welding parameter. For this purpose, FISBA can supply a pyrometer option (PyroS) with integral process-temperature control. This provides non-contact temperature measurements, and closed-loop control of the laser's output for any given nominal temperature. That eliminates practically any variation in material properties, processing speed, and other process parameters. It makes processes robust and repeatable, capable of meeting the most stringent quality specifications. It also permits integral data acquisition, to provide a continuous record of all welding processes performed.

Laser welding briefly explained

There is a choice of two basic welding methods: transmitted-light and butt welding. In either case, the two parts to be welded together must be gently pressed against each other, to provide the welding pressure essential for a strong seam. In transmitted-light welding, one of the materials must be transparent to the laser beam and the other opaque. The laser energy that passes through the transparent material is absorbed by the opaque material and melts the plastic. This creates a thermal bridge to the transparent material. A special dye additive helps the plastic to absorb the laser beam. Thus, for example, it enables a plastic material transparent to the laser beam to become opaque to the human eye. By contrast, in butt welding, both materials must be opaque. Transmitted-light welding results in particularly

strong, dense seams. Various materials may be combined. And no vibration occurs, such as is typical for other welding processes.

Materials suitable for welding

A wide choice of thermoplastics is suitable for laser processing. It makes it possible, practically without limitation, to weld low-melting-point plastics, such as PMMA, PS, ABS, PVC, POM, PBT, PET, and PC, and to combine them with one another. The laser can also weld high-melting-point and fluorinated plastics, such as LCP, PEEK, PSU, and EFTE. But as these materials have a very narrow processing-temperature window, the pyrometer option is often used to control welding temperature, and to prevent burns and breaks in welds.

Use in welding plant

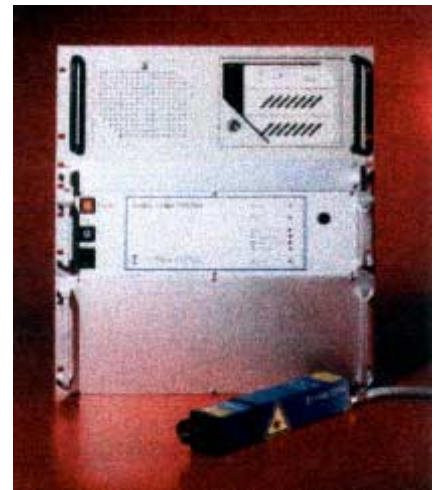
The lightweight, compact laser head is an ideal tool for fitting to xyz-shift systems and small robots. Because laser radiation is a hazard for the human eye, the plant must be optically isolated. Depending on layout, welding speeds from 3 to 150 millimeters (0.05 to 2.5 meters) per second are obtainable. High beam quality also makes the FISBA high-performance diode lasers suitable for use with scanner units. Two tilting mirrors allow a galvanoscanner to position the laser beam precisely and quickly. The laser beam is easy to position without the need to move the components to be welded together. Further, process time can be reduced because several welding sites can be processed almost synchronously.

To sum up

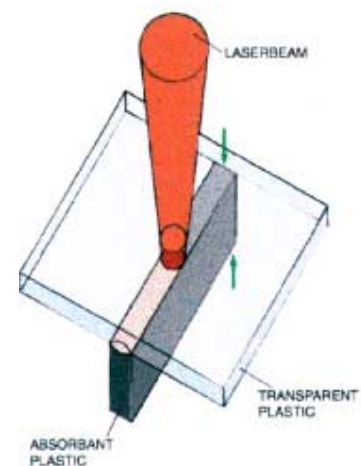
High-performance diode lasers have earned their firm place as universal tools in modern production. Besides the welding of plastics, they are also suitable for use in other processes, such as selective soldering and metal welding. A single workstation now

often combines such processes, an approach that favorably affects not only processing time, but also maintenance costs.

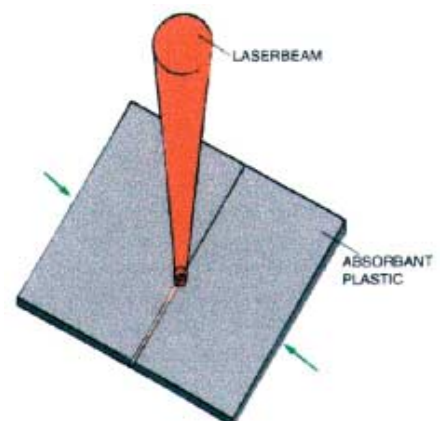
Further information from Fisba Optik AG, Rorschacherstrasse 268, 9016 St Gall, Switzerland, Tel: +41 71 282 3131, internet www.fisba.ch



1. FISBA FLS iron laser system with PyroS pyrometer option



2 a. Transmitted-light welding



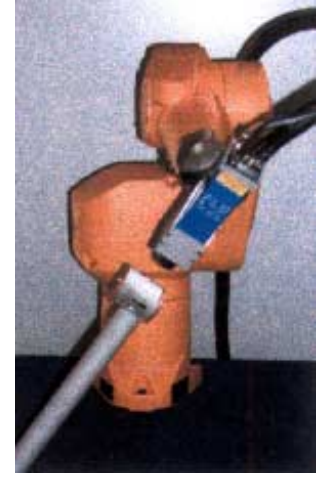
2 b. Butt welding



3. PA can: compression strength to 59bar.



4. Welding black and opal POM.



6. Robot in use with FLS iron.



5. Compact welding plant with FLS iron and xyz-shift unit.



7. FLS iron in use with scanner unit.

Lasersvetsning av tjockt konstruktionsstål

Ny svetsteknik på frammarsch för den tyngre industrin

Av Hans Engström, Klas Nilsson, Jan Flinkfeldt, Luleå tekniska universitet, Luleå
Tony Nilsson, SSAB Tunnsplåt AB, Borlänge
Anders Skirfors, SSAB Oxelösund AB, Oxelösund
Marcus Miller, Volvo Articulated Haulers AB, Växjö

Industriell lasersvetsning av konstruktionsstål i tjocklek större än ca 5 mm är än så länge begränsad i användning jämfört med metodens användning för tunnplåt och maskinbearbetade detaljer. Behovet av en ny svetsprocess för det tyngre materialet har dock varit uppenbart en tid på grund av väsentliga begränsningar som, hög värmeförlust och därmed stora deformationer, låg svets hastighet och små inträngningsdjup för de

använda konventionella svetsteknikerna.

Lasersvetsning ger många fördelar jämfört med de konventionella svetsteknikerna. Värmeförlusten är väsentligt lägre vilket ger små eller obetydliga deformationer och därmed minskar behovet av riktning och efterbearbetning av de svetsade komponenterna. Lasersvetsning ger också väsentligt högre svets hastigheter och stora inträngningsdjup vilket ger

mycket effektiv och snabb sammanfogning av material upp till ca 15-20 mm material tjocklek. Detta medför att man i flera fall kan utveckla radikalt nya konstruktionslösningar som kan produceras med färre antal operationer i tillverkningskedjan.

Sedan några år tillbaka finns också lasrar kommersiellt tillgängliga med den effekt och driftsäkerhet som krävs för industriell svetsning av tjockt material. Utvecklingen fortgår

alltjämt mot ännu högre effektnivåer både för CO₂- och Nd:YAG-lasrarna. Motsvarande utveckling av processteknik och svetsning av olika applikationer pågår också, främst inom varvsindustrin.

I detta projekt, som finansieras av Ferruform AB (fd Scania Chassikomponenter AB, Luleå), Volvo Construction Equipment AB, SSAB Tunnpå AB, SSAB Oxelösund AB, AGA AB och NUTEK, ska lasersvetsmekaniken utvecklas för företrädesvis höghållfast konstruktionsstål tjockare än 5 mm. Projektet, som utförs tillsammans med Luleå tekniska universitet, Avd. för bearbetningsteknik, ska också kartlägga möjligheter och begränsningar för lasersvetsning av dessa material och tjocklekar. Några aktuella frågeställningar är:

- Kan lasersvetsning utföras med godkänt resultat på stålqualitéer utvecklade för och använda av tung verkstads- och fordonsindustri
- Vilka tjocklekar kan lasersvetsas med godkänt resultat
- Vilka är kraven på fogberedning
- Vilka spalter kan tolereras
- Vilka åtgärder är nödvändiga för att i förekommande fall eliminera porer och andra svetsdefekter.

2. Experimentella data

2.1 Laserutrustning

Tabell 1. Använda lasrar

Laser	I	II	III
Maximal effekt [kW]	6	12	17
Fokallängd [mm]	275	270	300
Stråldiameter [mm]	0,5	0,5	0,8
Skyddsgas	He	He, He/CO ₂ , He/Ar	He, He/O ₂
Skyddsgas konfiguration	Sidoblås	Koaxiell dysa 4x 1,2 mm	Koaxiell dysa + sidoblås

Tabell 2. Stålsammansättning för de undersökta Domex stälen (vikts-%).

Stålsort	C	Si	Mn	P	S	N	Al	Nb	Ti	V	CE ¹⁾
Domex 280 YP, 8 mm	0,06	0,22	0,36	0,006	0,010	0,005	0,047	-	-	0,008	0,13
Domex 420 YP, 8 mm	0,06	0,01	0,60	0,009	0,006	0,006	0,048	0,050	-	0,005	0,17
Domex 700 MC, 6 mm	0,07	0,27	1,63	0,010	0,002	0,007	0,034	0,061	0,113	0,015	0,37

1) CE(%) = C + Mn/6 + (Cr+Mo+V)/5 + (Cu+Ni)/15 (kolekvivalent enligt IIV)

Tabell 3a. Mekaniska egenskaper för de undersökta Domex stälen.

Stålsort	Re (MPa)	R _m (MPa)	A ₅ (%)	Charpy-V seghet ¹⁾ Joule/cm ² / °C
Domex 280 YP, 8 mm	280	389	40	-
Domex 420 YP, 8 mm	455	536	28	348 / -20
Domex 700 MC, 6 mm	721 ¹⁾	799 ¹⁾	25 ¹⁾	127 / -40

1) Längsprov.

Tabell 3b. Svetsparametrar vid lasersvetsning (stumsvets) av Domex kallformningsstål.

Stålsort	Tjocklek (mm)	Effekt, P (kW)	Svets hast., v (m/min)	Str.energi, Q ¹⁾ (kJ/mm)	Δt _{8/5} ²⁾ (s)
Domex 280 YP	8	5	0,90	0,33	ca 1
Domex 420 YP	8	5	0,60; 0,80	0,38; 0,50	ca 2 - 3
Domex 700 MC	6	5	1,20	0,25	<1

1) Q = P (kW) x 60 / v (mm/min)

2) Δt_{8/5} = svalningstid mellan 800°C och 500°C.

2.2 Stålkvaliteter

Domex kallformningsstål

Tre olika kallformningsstål i Domex serien ingick i undersökningen: Domex 280 YP (8 mm), Domex 420 YP (8 mm) och Domex 700 MC (6 mm). Domex kallformningsstål är höghållfasta bandvalsade stål med förbättrade bockningsegenskaper jämfört med vanliga konstruktionsstål. Stålsammansättning och mekaniska egenskaper för de provade stälen framgår av tabell 2 och 3a. Stålsammansättningen karakteriseras av låg kolhalt och

hög slaggenhet för att förbättra bockbarheten. Den höga hållfastheten erhålls genom tillsatser av mikrolegeringselement (Nb, Ti, V) i kombination med termomekanisk valsning. I förhållande till hållfastheten är kallformningsstälens kolekvivalentvärden mycket låga som är speciellt bra vid svetsning med låga sträckenergier som ger snabba svalningstigheter.

Lasersvetsningsförsöken genomfördes med en CO₂-laser vid Luleå Tekniska Universitet. Svetsstypen var stumsvets. Inledande försök visade att det blev problem vid svetsning med klippta kanter därför användes frästa kanter vid de efterföljande försöken. Svetsningen gjordes från en sida och med en sträng. Som skyddsgas utnyttjades He och svetsningen utfördes utan något tillsatsmaterial. Övriga svetsparametrar framgår av tabell 3b. Från tabellen framgår tydligt de låga sträckenergierna och de snabba svalningstiderna (se Dt_{8/5}) vid lasersvetsning.

Följande provningar genomfördes för att undersöka de lasersvetsade förbanden (stumsvetsar): visuell kontroll, röntgen, makroprov, hårdhetskurvor, bockprovning, dragprov tvärs svets, slagseghet.

WELDOX och HARDOX

SSAB Oxelösund tillverkar konstruktionsstål med sträckgränser upp till

1100 MPa (WELDOX 1100), och slitstål med hårdheter upp till 600 HB (HARDOX 600). WELDOX 1100 är idag det mest höghållfasta konstruktionsstålet, och HARDOX 600 det hårdaste slitstålet som finns tillgängligt på marknaden.

I den här undersökningen har lasersvetsbarheten av ett konstruktionsstål, WELDOX 500, och ett slitstål, HARDOX 400, undersökts. Den kemiska

sammansättningen och de mekaniska egenskaperna hos de studerade plåtarna framgår av tabell 4 och 5.

Svetsparametrarna, som visas i tabell 6, har valts i syfte att erhålla en svalningstid mellan 800 och 500°C ($\Delta t_{8/5}$) på mellan 1-5 s.

Tabell 4. Sammansättning för WELDOX 500 och HARDOX 400

Material	t mm	C	Si	Mn	P	S	Cr	Ni	Mo	V	Ti	Cu	Al	Nb	B	CE _{IV} ¹
WELDOX 500	6	,087	0,24	1,49	,008	,002	,028	,057	,015	,083	,009	,030	,030	,038	0	0,37
HARDOX 400	10	,127	0,46	1,37	,008	,002	,029	,038	,008	,009	,032	,010	,044	,023	,002	0,37
HARDOX 400	15	,135	0,44	1,39	,009	,001	,022	,043	,011	,008	,031	,019	,028	,024	,002	0,38

1) $CE_{IV} = C + Mn/6 + (Cr+Mo+V)/5 + (Cu+Ni)/15$

Tabell 5. Mekaniska egenskaper hos WELDOX 500 och HARDOX 400

Material	t (mm)	Leverans- tillstånd	Re (MPa)	Rm (MPa)	A5 (%)	CVL	Hårdhet (HB)
WELDOX 500	6	M	536	600	24	174J/-50°C ¹	-
HARDOX 400	10	Q	-	-	-	30J/-40°C ^{1,2}	408
HARDOX 400	15	Q	-	-	-	50J/-40°C ²	400 ¹

1) Provdimension 5x10 mm; 2) Typiskt värde

Tabell 6. Svetsparametrar

Material	t (mm)	P (kW)	v (m/min)	Q (kJ/mm) ¹	$\Delta t_{8/5}$ (s) ²
WELDOX 500	6	5,0	2,4	0,12	1
WELDOX 500	6	5,0	1,2	0,25	2
WELDOX 500	6	3,0	0,4	0,45	5
HARDOX 400	10	10,5	2,4	0,26	1
HARDOX 400	10	10,5	1,7	0,37	2
HARDOX 400	10	10,5	1,0	0,63	5
HARDOX 400	15	17,0	1,1	0,93	5

¹) Q (sträckenergi) = P (kW) x 60/v (mm/min)

²) $\Delta t_{8/5}$ = svalningstid mellan 800 och 500°C

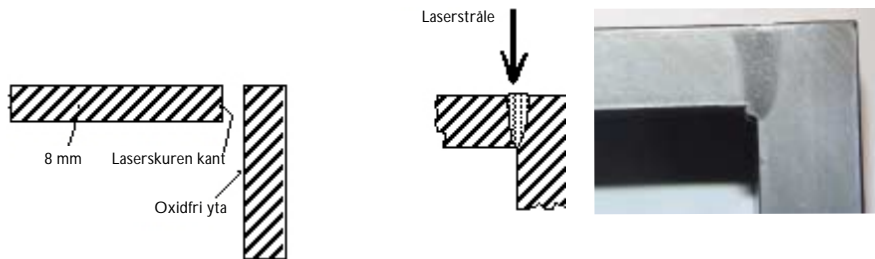
Följande provning utfördes: dragprovning, slagseghetsprovning (Charpy-V), hårdhetsmätning, strukturandelsbestämning och makrofotografering.

2.3 Fogtyper och fogberedning

Vi har gjort försök med tre olika fogtyper; i) I-fog utan tillsatsmaterial med laserskuren och fräst kant, ii) I-fog med laserskuren kant och V-fog

båda med tillsatsmaterial, iii) hörnfog, figur 1.





Figur 1. Fogberedning och svetsning av hörnfog.

2.4 Tillsatsmaterial

Tillsatsmaterial har använts för att eliminera inverkan av materialunderskott som uppstår vid svetsning med spalt, vilket ger svetsdiken, samt för att påverka svetsprocessen så att svetsdefekter kan undvikas. Det tillsatsmaterial vi har använt är ESAB OK Autrod 12.51, $\phi=1,0$ mm.

3. Resultat

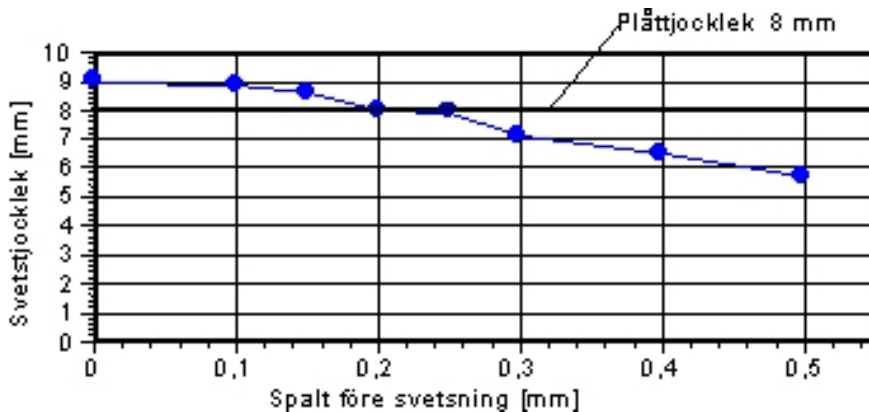
3.1 Tillåten spalt

Det finns alltid i praktiken en spalt (om än liten) vid svetsning av I-fog även om kanterna är maskinbearbetade. Detta behöver inte vara ett problem vid svetsning utan tillsatsma-

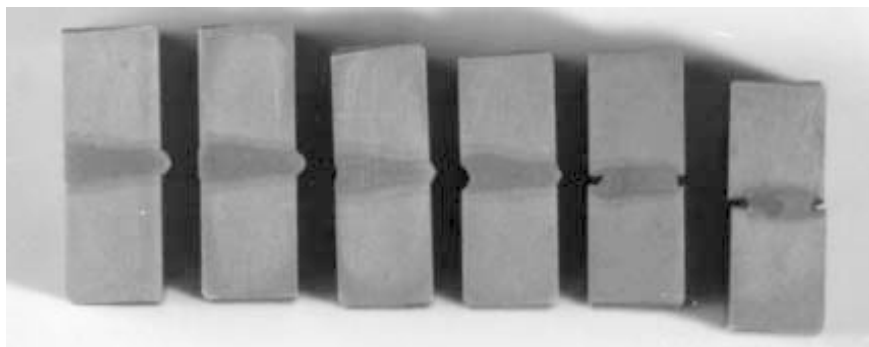
terial eftersom det sker en krympning i svetsfogen vid stelmandet som gör att man faktiskt får en råge om fogen är väl preparerad och har släta ytor. Krympningen är större för tjockt material varför man normalt kan tillåta en större spalt. Vi har gjort försök i 8 mm material med laser I som visar att resultatet blir optimalt, dvs varken råge eller svetsdike uppstår, om spalten är 0,2-0,25 mm, figur 2. I figur 3 visas tvärsnitt av dessa svetsar, med ökande spalt från 0,0 mm i steg om 0,1 mm upp till 0,5 mm.

3.2 Domex kallformningsstål

Den visuella kontrollen visade att svetsarna såg ganska bra ut. Det var mycket små tendenser till sprut.

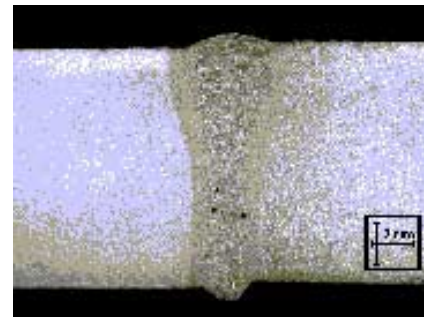


Figur 2. Uppmått svetsjocklek vid olika spalter för maskinbearbetade ytor.

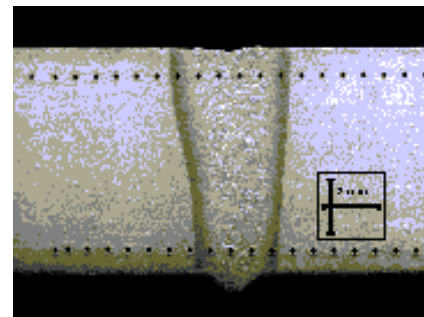


Figur 3. Tvärsnitt av svetsar med ökande spalt.

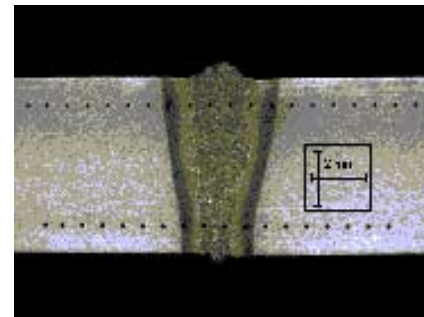
Exempel på makroprover framgår av figur 4. Svetsgeometrin är bra med ett fint V-format utseende. Några av svetsarna uppvisade dock små insjunkningar och mindre kantförskjutningar. Från makrofotografierna syns också att svetsarna är smala och utbredningen av de värmepåverkade zonerna (HAZ) är väldigt små. Det beror i sin tur på den låga sträckenergin som är typiskt för lasersvetsning. Från röntgenprovningen framgick det att de flesta av svetsarna uppvisade inre porer. Mängden porer var dock så liten att de mekaniska egenskaperna ej påverkas av dessa. Inga andra defekter eller sprickor upptäcktes.



a)

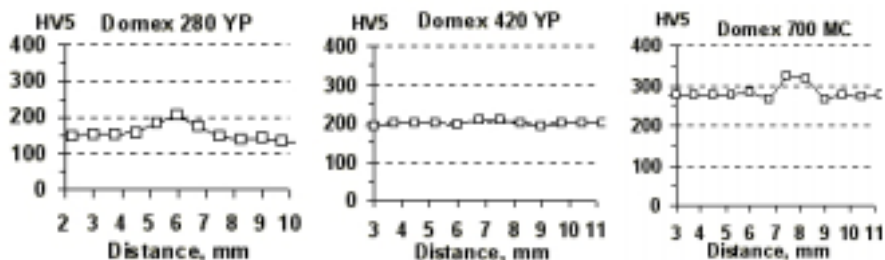


b)



c)

Figur 4. Makrofoton av lasersvetsarna. a) Domex 280 YP, 8 mm. b) Domex 420 YP, 8 mm. c) Domex 700 MC, 6 mm. (De små punkterna nära över- resp underytan för foto b) och c) är intrycksmärken från hårdhetsprovningen).



Figur 5. Hårdhetskurvor tvärs svetsen för Domex stälen.

Hårdhetskurvor tvärs lasersvetsarna för de tre Domex stälen visas i figur 5. Hårdheten i svetsarna är något högre än i basmaterialet (mikrostrukturen i svetsgodset är en typ av finkorning acikulär ferrit). Lasersvetsarna har inga mjuka zoner i HAZ vilket är vanligt vid MAG-svetsning speciellt för stälet med den högsta hållfastheten (Domex 700 MC).

Bockbarhetsprovning (30 mm breda prover med bockningslinjen parallell med svetsen, 120° bockningsvinkel) visade att svetsarna har bra kvalitet. För alla tre Domex-stälen

användes en dornradie av 2 x plåtjockleken och inte i något fall erhöles några sprickor vid bockningen. Porerna som syntes vid röntgenprovningen har uppenbarligen inte försämrat svetskvaliteten i någon nämnvärd omfattning.

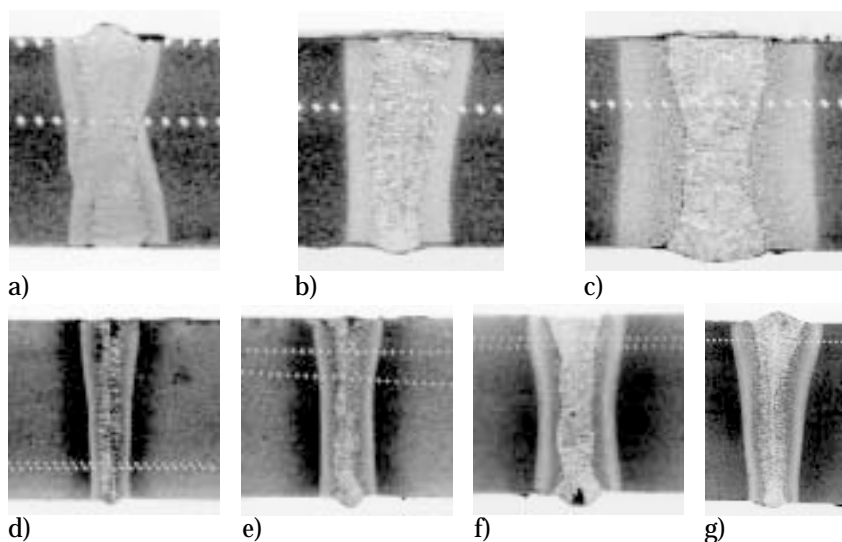
Resultat från hållfasthets- och slagseghetsprovningen av de lasersvetsade Domex stälen framgår av tabell 7. Brottläget vid dragprovningen är ute i basmaterialet. Detta gäller för alla tre stälen och för alla de provade svetsastigheterna. Det innebär att svetsarna har högre hållfast-

het än basmaterialet och det är ju vad som eftersträvas. De uppmätta slagseghetsvärdena i svetsarna för stälen Domex 420 YP och Domex 700 MC ligger på ungefär samma nivå som basmaterialets slagseghet. De mekaniska egenskaperna i de lasersvetsade förbanden är alltså minst lika bra som egenskaperna i basmaterialet. Anledningen till de goda mekaniska egenskaperna hos lasersvetsarna är den låga sträckenergin som ger snabb svalning och därmed en finkorning mikrostruktur med bra hållfasthet och slagseghet.

3.3. WELDOX och HARDOX

Svetskvaliteten var generellt mycket bra, figur 6. Några svetsar innehöll en mindre mängd porer. Inga sprickor eller andra defekter detekterades.

Svalningstiden $\Delta t_{8/5}$ är mycket betydelsefull för hårdheten i svetsen. Svetsgodset och den värmepåverkade zonen (HAZ) i WELDOX 500 uppvisar högre hårdhet än grundmaterialet pga den snabba svalningen, figur 7a. Tack vare den låga kolhalten begränsas dock den maximala hårdheten till "ofarliga" värden (kolhalten bestämmer martensitens hårdhet).



Figur 6. Makrofotografier av svetsförband:

- a) WELDOX 500, 6 mm, $\Delta t_{8/5} = 1$ s.
- b) WELDOX 500, 6 mm, $\Delta t_{8/5} = 2$ s.
- c) WELDOX 500, 6 mm, $\Delta t_{8/5} = 5$ s.
- d) HARDOX 400, 10 mm, $\Delta t_{8/5} = 1$ s.
- e) HARDOX 400, 10 mm, $\Delta t_{8/5} = 2$ s.
- f) HARDOX 400, 10 mm, $\Delta t_{8/5} = 5$ s.
- g) HARDOX 400, $t = 15$ mm, $\Delta t_{8/5} = 5$ s.

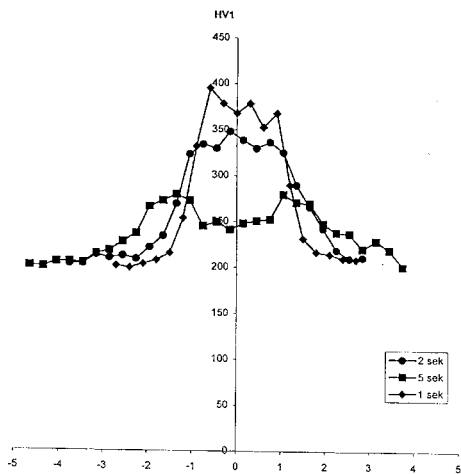
Tabell 7. Hållfasthets- och slagseghetsresultat för de lasersvetsade (stumsvetsar) Domex stälen (proverna har tagits ut tvärs svetsen).

Stälsort	Svetsast. (m/min)	R_e (MPa)	R_m (MPa)	A_5 (%)	Brottläge	Charpy V ²⁾ Joule/cm ² / °C
Domex 280YP, 8mm	0,90	295	403	29	BM ¹⁾	
Domex 420YP, 8mm	0,60	448	544	24	BM	
	0,80	448	539	23	BM	117(A ³⁾),302(C ³⁾) /-40
Domex 700MC, 6mm	1,20	738	813	19	BM	223(A ³⁾),105(C ³⁾) /-40

1) BM = Basmaterialet

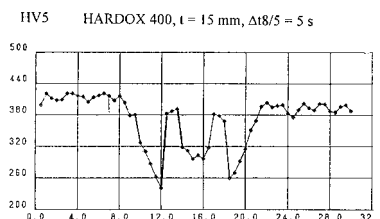
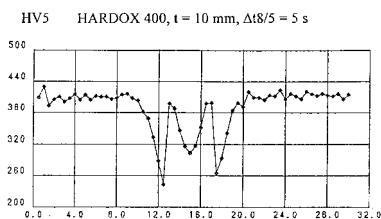
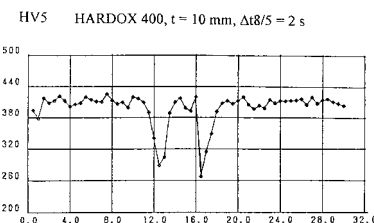
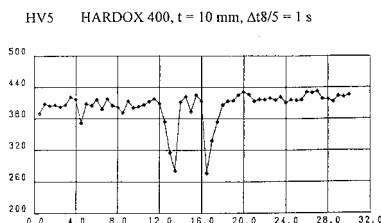
2) Längs valsningsriktningen.

3) A = Svetsgodset, C = HAZ (1 mm från smältgränsen)



a)

Figur 7a) Hårdheten (HV1) för olika svalningstider ($\Delta t/5$) i svetsförband av WELDOX 500. Hårdheten är uppmätt tvärs svetsen längs en linje 1,5 mm under plåtytan.



b)

7b) Hårdheten (HV5) i lasersvetsade förband med olika svalningstider av HARDOX 400. Hårdheten är uppmätt tvärs svetsen längs en linje 2 mm under plåtytan.

HARDOX 400 är en härdad slitplåt. Svetsen är mjukare än grundmaterialet, figur 7 b. Den mjuka zonen är dock smalare jämfört med förband svetsade med konventionella bågsvetsmetoder. Det medför förbättrade slitageegenskaper i svetsförbandet.

Den metallografiska undersökningen visar tillsammans med den mekaniska provningen att mycket

goda mekaniska egenskaper erhålls i lasersvetsförband av WELDOX 500 trots höga halter av martensit och bainit, se tabell 8 och 9.

Svetsförbanden i HARDOX 400 erhåller bra slagseghetsvärden ned till en svalningstid av 2 s, tabell 9. För de flesta slitageapplikationer är dock slagsegheten som erhålls vid $\Delta t/5 = 1$ s fullt tillräcklig.

4. Applikationstest

En lådbalk av ny konstruktion, delvis visad i figur 1, svetsades av Domex 355 med Laser I. Tjockleken på topp- och bottensektionen var 8 mm och livet var 10 mm. Balkens längd var 2000 mm. Totalt tillverkades sex balkar varav tre användes för böjutmattningsförsök och tre för att prova vridutmattning.

Tabell 8. Strukturandelsbestämning av svetsgods i lasersvetsade förband av WELDOX 500 som en funktion av svalningstiden $\Delta t/5$.

$\Delta t/5$ (s)	% Ferrit	% Perlit	% Martensit	% Bainit	Mikrostruktur i HAZ
1	-	-	81	19	Martensit/Bainit
2	-	-	65	35	Martensit/Bainit
5	15PF, 75AF	-	-	10	Bainit
Grundmaterial	85PF	15	-	-	

PF= polygonal ferrit, AF= acikulär ferrit

Tabell 9. Statisk hållfasthet och slagseghet.

Material	t (mm)	$\Delta t/5$ (s)	Re (MPa)	Rm (MPa)	A50 (%)	Brottläge	Slagseghet vid -40°C (J) Provstavsdimension: 5x10 mm Sv.G/HAZ
WELDOX 500	6	1	-	585	36	BM	54/48
WELDOX 500	6	2	-	590	36	BM	68/37
WELDOX 500	6	5	-	581	28 ¹	BM	63/64
HARDOX 400	10	1	1114	1230	7	HAZ	23/8
HARDOX 400	10	2	1108	1213	6	HAZ	30/15
HARDOX 400	10	5	1032	1058	4	HAZ	20/22
HARDOX 400	15	5	1011	1108	8	HAZ	30/27 ²

1) A5 %

2) Provdimension 10x10mm

Böjning

Vid böjutmattning belastades balkarna med ± 75 , ± 60 , och ± 50 kN, figur 8. Motsvarande cykler innan brott blev 248 800, 723 200 och 1 258 900. Dessa resultat var i samma nivå eller bättre jämfört med MAG-svetsade balkar av konventionell design.



Figur 8. Rigg för böjutmattningsprov av lasersvetsad lädbalk.

Vridning

De lasersvetsade balkarna testades också under vridutmattning. Preliminära resultat visar att hållfastheten ligger på samma nivå som MAG-svetsade balkar. Detta prov har visat betydelsen av att svetsarna inte har några bindfel. Nya vridutmattningsprov skall utföras för att komplettera tidigare resultat.

5. Konstruktionsmöjligheter

Tack vare små deformationer och stort penetrationsdjup så har laser-

svetsning stora möjligheter att påverka konstruktionen av olika lastbärande element, som t ex lädbalkar. Men lasersvetsning kräver noggrann fogberedning för att få minimala spalter vid stumfogs svetsning. Genom att använda noggrant preparerade delar tillverkade genom t ex laser-skärning, och den minimala deformationen så ger lasersvetsningen högre precision hos svetsade delkomponenter. Dessutom kommer inte bearbetade komponenter att deformeras vilket gör det enklare att fästa lager och andra komponenter. Lasersvetsade fogar kan också placeras närmare bearbetade ytor vilket ger möjligheter till mindre och mera lätthanterliga delmontage.

Lokala förstärkningar kan också svetsas "in-plane" istället för "off-set plane" utan komplicerad fogberedning, vilket medför en mera gynnsam väg för kraftflödet. Lasersvetsning är en fullpenetrerade svetsmetod, vilket ger mindre anvisningar jämfört med konventionell svetssteknik, och därmed får den svetsade strukturen högre hållfasthet vilket kan utnyttjas till att bära större laster eller sänkt vikt.

6. Slutsatser

Detta arbete har tydligt visat utmärkta svetsresultat vid lasersvetsning av

kallformnings-, konstruktions-, och slitstål.

Lasersvetsade förband i Domex kallformningsstål ($t = 6-8$ mm) visar mycket goda formningsegenskaper samt hållfasthet och seghet som är minst lika bra som för grundmaterialet.

Lasersvetsade förband av WELDOX 500 ($t = 6$ mm) erhåller mycket goda mekaniska egenskaper trots svalningstider $\Delta t_{8/5}$ ned till 1 s.

Lasersvetsade förband i HARDOX 400 ($t = 10-15$ mm) erhåller goda mekaniska egenskaper ned till en svalningstid $\Delta t_{8/5}$ på 2 s.

Böjutmattningsprov visar att lasersvetsade lädbalkar har samma eller bättre hållfasthet som motsvarande MAG-svetsade balkar.

Detta projekt ingår som en del i RACER, ett industridrivet utvecklingsprogram för laser och vattenstrålebearbetning finansierat av NUTEK och svensk industri.

Upplysningar om

RACER-programmet finns på [www. mb.luth.se/mpb.htm](http://www.mb.luth.se/mpb.htm) eller kontakta

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EuroCarBody 2000

Volvo V70 – Harmonizing Product and Manufacturing Aspects

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Abstract

In early 2000 Volvo launched its latest estate model, the new Volvo V70. This is the second product built on the

larger P2x platform, following the S80 sedan version, which was introduced in May 1998. The V70 car bo-

dies are scheduled to be manufactured in the flexible body shops in both Torslanda, Sweden and in the Belgian

Gent plant. Among the more highlighted features are a transversely mounted in-line five cylinder engine with a specially designed gear-box, electronic multiplex technology with 18 computers in the network, and safety features like stability and traction control (STC), front seats with integrated anti-whiplash system (WHIPS) and inflatable curtain (IC) for improved side impact protection.

To fulfill the product's high demands on safety, quality and environmental care, the design, materials selection and assembly of the car body with high precision had to be very carefully engineered. As in previous product-/process development a holistic and concurrent engineering approach was necessary.

In order to minimize car body weight as a consequence of lower fuel consumption, but maintain high product properties in terms of stiffness, energy absorption and fatigue, some 40% of the overall body weight is represented by various grades of high strength steels, such as rephosphorized and dual-phase qualities. For the rear bumper beam, a Boron alloyed steel with >1000MPa in ultimate strength was chosen. For these material qualities, welding process data had to be adjusted to assure superior weld quality.

To lighten the BIW even more, aluminium was used for the hood, whereas the tailgate is a fiber-reinforced plastic component manufactured by using the SMC technique. This method showed to be the only one which offered an acceptable parts cost and weight for the complex shaped tailgate. No welding is used for the aluminium hood, but only mechanical clinch joining.

Laser welding, utilized by Volvo since 1991, was further improved for the S80 and V70 production. The laser welding cell, situated in the main production line, is equipped with two laser sources and adherent robotized beam guidance system. These robots are working in parallel in order to shorten cycle time. The flexible body shop, with multi-tooling for high pre-

cision reasons, gave the possibility to launch and ramp up the V70 production as the second product (1. product Volvo S80) on the same line without loosing S80 customer cars.

As the V70 car body comes in two versions, "E" (estate) model and "L" (leisure) model, variant hole cutting utilizing a 500W Nd:YAG laser, is used at the very end in the main production line.

This paper will describe some of the topics mentioned above, with a specific attention to the interactive work between materials development and the choice of adequate joining processes. Also the measures taken to upgrade the global torsion stiffness of the V70 will be thoroughly described.

Introduction

Today there is a strong environmental awareness among the automotive manufacturers. One reason for this is to be able to fulfill governmental requirements like the CAFE (Corporate Average Fuel Economy) regulations in the United States and similar legislation now being discussed in many other countries. But another incentive is related to a more global environmental concern with the purpose to offer the car customer a product, which has a low energy consumption and that detriments our nature as little as possible.

In previous body engineering, almost just one material occurred, namely mild steel. Today the material scenario contains different grades of high strength steels with different kinds of surface coatings. From weight saving aspects an increased amount of aluminium and plastic composites is also an ingredient in modern car bodies. In regard to this a new joining technologies palette has to be used when engineering light weight structures, something that become obvious when developing the V70. The necessity to develop materials and joining technologies in an integrated process very much contributed to the "above-average" properties that the car body of the V70 reveals.

Selection of materials and joining Methods

To be able to design a car body with outstanding crash behaviour, different grades of high strength steel were used, particularly in impact severe areas like front and rear side members, B-pillars (for side impact) and roof bows (for rollover). More than 40% [Fig. 1] of the total BIW weight consists of rephosphorized steels and Dual-Phase (DP) steels with yield strengths of about 250 MPa and 400MPa respectively. With that approach it has been possible to maintain the high safety standards without adding considerable weight.

This is also the result of a strategic development of high strength steels, which started in the mid 80's with the introduction of some parts manufactured in HSLA (High Strength Low Alloy) grades for the Volvo 700 series. One of the first applications in HSS was the front side member of the 740 model, and the reason for the introduction was to upgrade this car model in regard to crashworthiness performance.

The high volume production requirements put on the V70 gave restrictions to the amount of aluminium used for the car body. In cooperation with other European car manufacturers, studies were performed to introduce aluminium parts in the structure, such as e.g. roof panel. Even if the results showed very promising, it was judged as these solutions were not fully quality proven and for that reason not fully mature for production. The range of aluminium components was therefore limited to hang-on parts.

As the door structure has an important role at both side and not least offset impact situations, the side doors are manufactured in steel with side-intrusion beams in UHSS (Ultra High Strength Steel). The hood is however a fully integrated aluminium subassembly. To avoid heat-input from welding operations, all joining is done utilizing either clinch joining or adhesive bonding. Zinc coated steel

and aluminium reinforcements are clinch joined to the AA5182 inner structure of the hood (20 clinches). In general round clinch tools are used as they have shown the best performance in terms of both product and process liability.

The assembly of the hood in the Olofstroem press plant is fully automated. The assembly cells are totally materials flexible so that also steel hoods can be produced here and assembled by using mechanical joining techniques. Typical key values for this kind of assembly line is 36 seconds cycle time and an overall availability of approximately 90%.

Simulation models for joint optimization

Engineers have traditionally relied on a combination of experimental and analytical techniques to verify vehicle performance. Today, the analytical design validation has only partly been realized. State-of-the-art tools for modelling vehicle structural performance i.e. stiffness, Eigen frequencies and crashworthiness are quite mature. For durability, on the other hand, analytical methods are still competing with experimental

tests to be the first available tool accurate enough to predict structural performance during the development of new vehicles. This is particularly true for joints, traditionally spot welds, used to assemble car body structures.

Efficient and reliable numerical methods to predict lifetimes of car bodies (including joints) are necessary in order to achieve designs with low weight, low manufacturing costs and good durability with a short development cycle. Highly stressed areas should be detected and re-designed at an early stage and before the first prototype series is manufactured. Numerical models have to be geometrically independent and should fit into existing Finite Element Models without increasing the complexity (i.e. without increasing the number of degrees of freedom in the model).

In order to shorten the lead-time for the product development process, advanced simulation tools are increasingly used for this purpose. This is also valid for the joining processes. Today there are softwares, which on a very detailed level can simulate the processes for welding (SYSWELD), clinching and riveting. They can be linked to other modules that can pre-

dict properties like static and fatigue strength of these joints.

On complete car body level, Volvo can today predict the fatigue behaviour of each single spot and arc weld in the structure. Moreover, a crash failure model for spot welds is just starting to be employed.

The spot weld fatigue model has been successfully used for more than four years now, and served as an efficient and reliable numerical method, during the development of the Volvo S80 and V70. Highly stressed areas could be detected and re-designed at an early stage and before the first prototype series are manufactured. This software system has been developed in the MSC/FATIGUE environment, which permits fatigue life predictions to be made for automotive spot welds joining two sheets. The method requires spot welds to be modeled as stiff beam elements in MSC/NASTRAN. Calculated cross-sectional forces and moments are then used to calculate the structural stresses in the weld nugget and at the inside of the adjoining sheet metal at intervals around the perimeter of the nugget. These stresses can then be used to make fatigue life predictions on the spot weld using the S-N (total

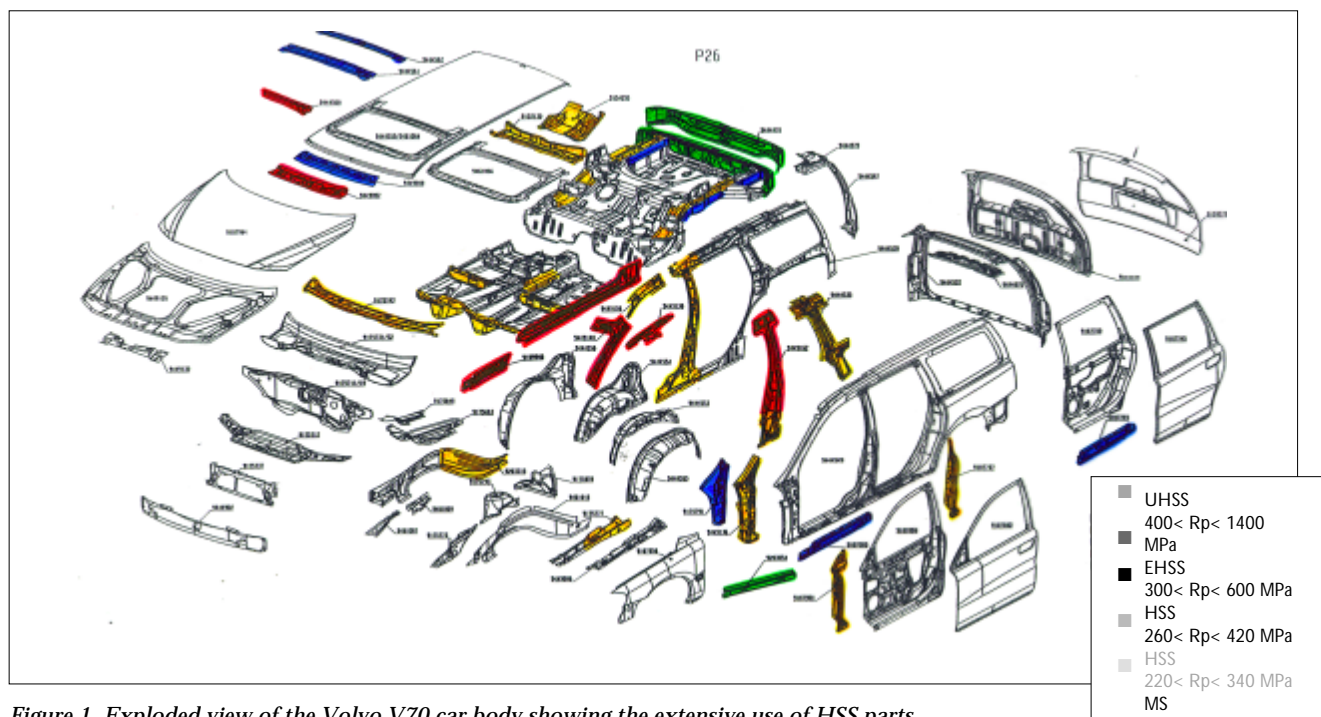


Figure 1. Exploded view of the Volvo V70 car body showing the extensive use of HSS parts.

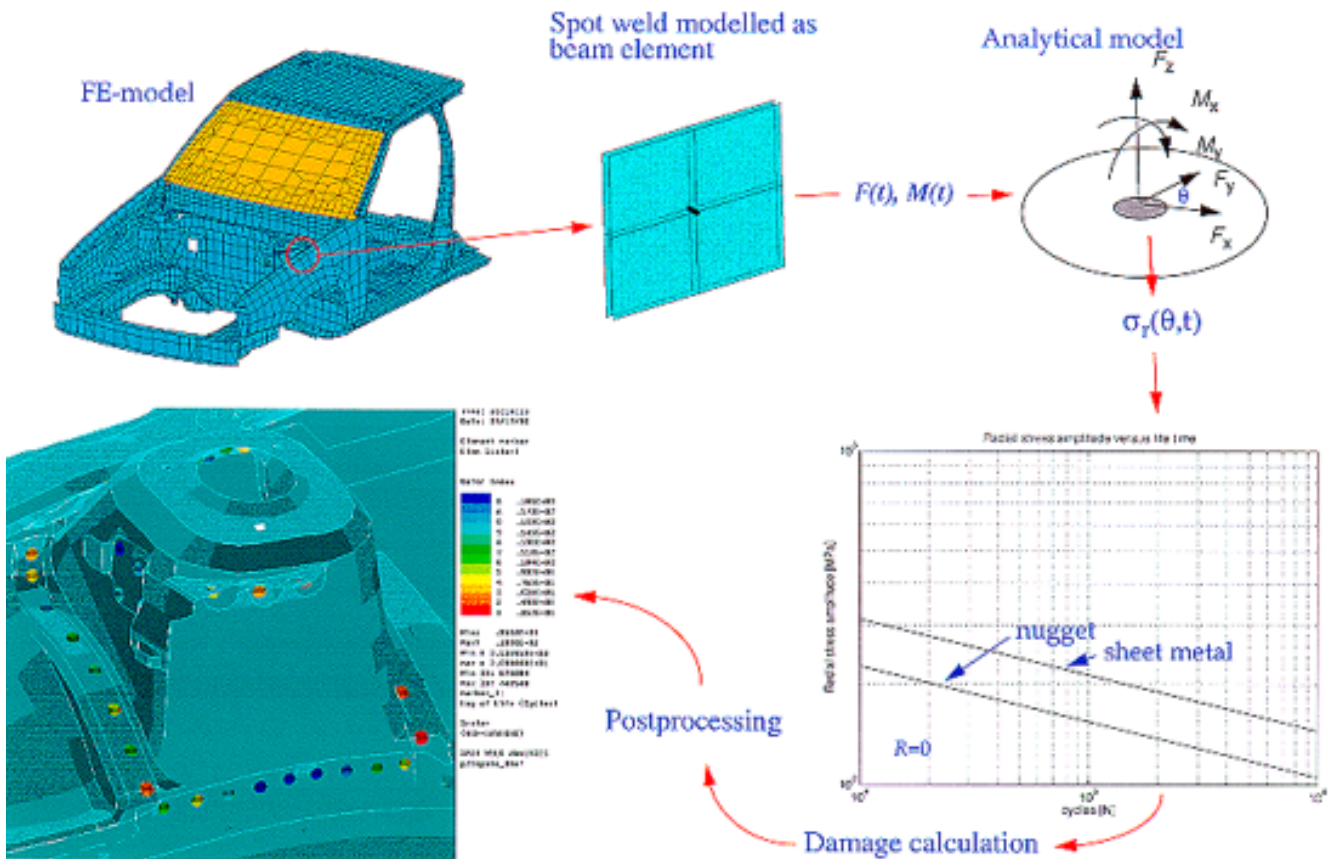


Figure 2. Principle of fatigue life prediction of spot welded structures.

life) approach [Fig.2]. The software is fully integrated in MSC/FATIGUE as a licensed tool. The method is geometry-independent and needs no extra refinement next to the weld elements (only correct length and orientation of the beam elements). The method has been found to be a powerful tool for identifying critical spot welds in complete car body models. In most cases also the correct sheet and angular position around these critical spots are found. The accuracy of calculated numbers of cycles to failure is however less reliable, but one explanation might be the inaccuracies in used loading histories.

Continuously welded thin sheet structures usually obtain fatigue failure located at the weld toes. The fatigue prediction method developed at Volvo uses nodal forces and moments calculated along the weld line together with an analytical expression for the structural stress at the weld toe. The calculated stress is a geometrical (hot spot) stress and is used together with an experimentally deter-

mined S-N curve. The geometrical stress does not include local effects, but is assumed to be highly related to the stress state that leads to fatigue failure. One advantage with the proposed method is that a rather coarse mesh can be used without losing too much accuracy in predicted fatigue life. The method has been found to give good results also at critical locations, such as weld starts and weld corners, without the need for element intensive refinements.

Calculations of structural stress for a wide range of different kinds of fatigue tested welded specimens show that there is a strong coupling between the amount of bending moment along the weld line and the slope of the S-N curve. A “stiff” joint with structural stress dominated by membrane forces is found to have a steeper S-N curve than a more “flexible” joint with structural stress dominated by bending moment. All test results could be fitted to two different S-N curves [Fig.3].

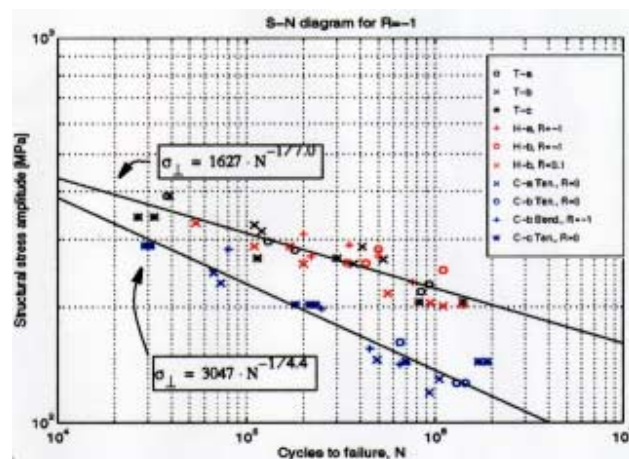


Figure 3. Test results from different kinds of welded thin sheet structures (thickness between 1 and 3mm, R-values between 0.1 and -1) fitted to two S-N curves. The lower, steeper curve is applicable for normal force dominated load cases. The higher, flatter curve is useful for bending dominated load cases.

Actions taken to upgrade global torsion stiffness

One of the biggest challenges for automotive body engineers is to achieve a high global stiffness of the car body, which is of vital importance regarding handling response, driving comfort and solidity. For a sedan model, the stiffness demands can be fairly easy met thanks to that parcel shelf, the structure behind the rear seat backrest and the structure surrounding the trunklid contributes to the stiffness together with the bonded rear window. However, for estate models this could not be reached for different reasons, the requirements for large load capacity being an obvious one. Therefore the engineer ends up with a large, square, open box structure with a poor rigidity. When engineering the new Volvo V70 model, these aspects were taken into consideration, and with the combination of various means, it became possible to increase the overall global static torsion stiffness with ~50% compared to the previous Volvo V70 estate wagon.

Among the contributions for increased stiffness the following topics could be mentioned:

- Redesign of the structure surrounding the tailgate opening
- Introduction of structural bonding in strategic areas
- Introduction of the "lion feet" reinforcement connecting the bodyside to the floor
- Laser welded tailored blanking.

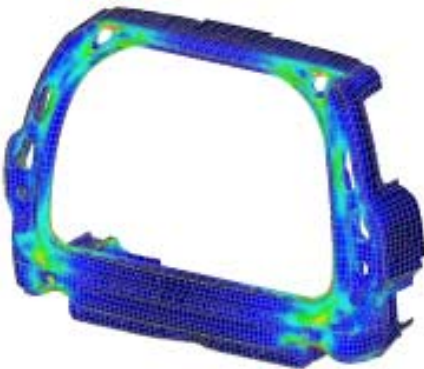


Figure 4. Stress analysis of V70 ringframe under torsion loading.

Half of the improvement comes from the geometrical section of the so-called ring-frame [Fig. 4] around the tailgate opening and its connection to the side members and the floor structure. The ring-frame is more robust, having D-pillars with closed sections [Fig.5], joined rigidly to the integrated rear bumper beam. These solutions are new compared to the predecessor.

Stiffness optimisation through FEM calculations has resulted in engineering solutions like tailored welded blanks and correct choice of material thickness. Using adhesive bonding instead of spot welding for the back panel cross-member has helped lowering the load floor level, gaining opening space and load capacity. Adhesive bonding has also been used in the upper corners of the tailgate adding considerable local strength and stiffness in these areas. Continuous bonding in itself makes a substantial contribution to stiffness over spot welding and also requires smaller flanges.

Another 30% of the improved stiffness were attributable to how the C-pillar, with its wide base, is connected to the wheel arch and the floor. On each side of the body were introduced reinforcements, which were nicknamed the "lion feet" [Fig. 6] (due to its resemblance) by the engineering team. Those reinforcements connect the rear wheelhouses with

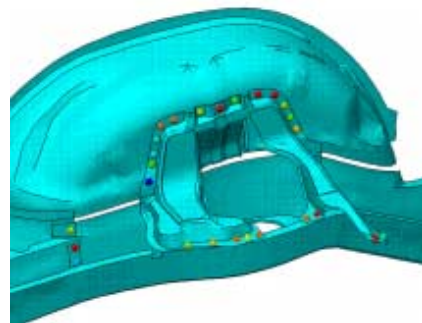


Figure 6. Spot weld fatigue analysis of the lion-foot connecting the wheel-house to the floor panel.

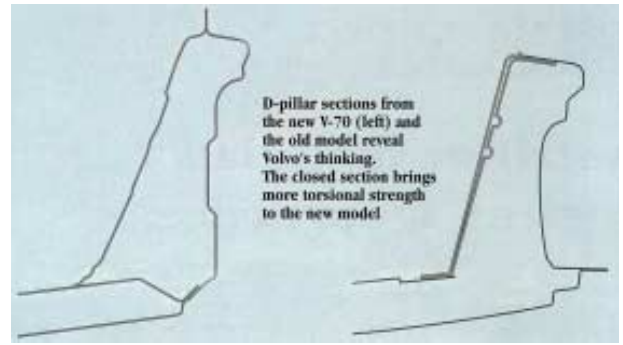


Figure 5. Comparison between the old (r.h.) and new (l.h.) D-pillar cross-section of the Volvo V70.

the floor and reaches out and over the suspension pots.

The remaining 20% were due to the A- and B-pillar design and refinement, which are features the V70 model shares with the S80 saloon on whose platform the V70 is based.

Tailored welded blanks of steels with different thickness and strength have been used in the front lower and upper side members, ring frame, body side inner and the B-pillar reinforcement.

Roof laser welding

Joining the roof to the body of a car has always been a critical operation due to design and process limitations. Traditionally, this has taken the form of seam welding, requiring access from both sides of the joint. In this respect, the alternative of laser beam welding offers a series of advantages, including

- necessity of access from one side only;
- new design and construction opportunities;
- reduced joint deformation;
- high static strength and fatigue strength,
- closer, more consistent body tolerances;
- tighter seam-welded joints.

In the Volvo S80/V70, S70 and 850 series, the drip moulding was eliminated and the roof panel is welded directly to the body side [Fig.7].

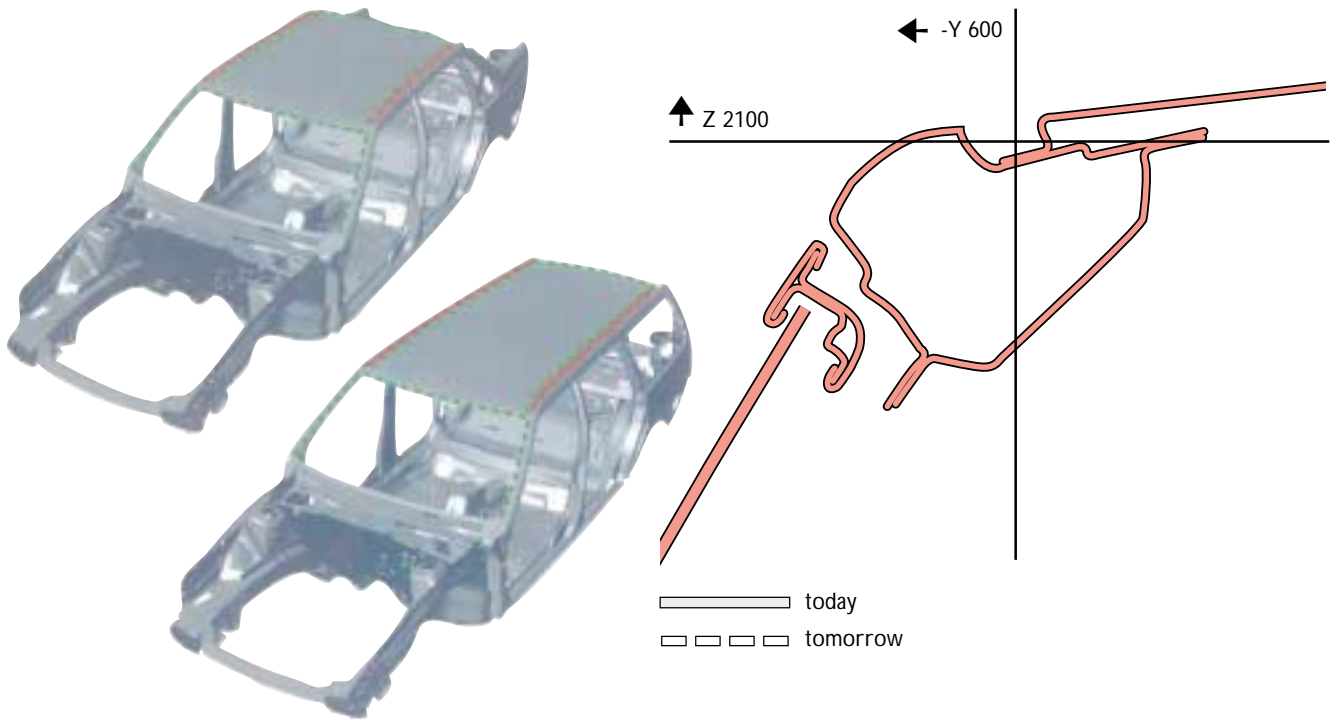


Figure 7. Volvo S80/V70, S70 and 850 roof/body side welding application.

Several assembly methods including spot welding, weld bonding and plug welding were feasible. However, laser beam welding was chosen for its unsurpassed characteristics, including its mechanical properties, in production flexibility and cost benefits. Flexibility was required to deal with the variety of models and variants to be produced in the body plant line, in addition to which the higher capital cost was more easily justified by dividing it among several different cars.

Industrial application

In the industrial context, the advantages of laser beam welding can be exploited only if the technical and economic risks are minimized [Fig. 8]. Preliminary design drawings of a production cell for welding roofs by this method were produced at an early stage of the development project. No commercial application of the method was available at that time (early 1987).

The design of production equipment employing a laser beam as energy source was not the primary objective at this time, nor was the search

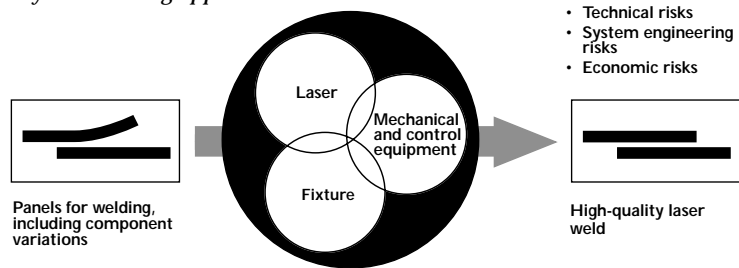


Figure 8 Requirements of laser beam welding.

for a fast, precise, high-performance robot. Instead, the most critical problem was to devise a method of fixing the components in position during the welding process.

Conventional fixtures, which are limited to a single application, are cumbersome and expensive, and cannot be changed simply in the welding station due to the short cycle times involved. Furthermore, access from two sides is often required.

The solution was to allow the mechanical system to follow the geometry of

the component while pressing the sheets together at the point of weld



Figure 9. First conceptual sketches of pressure roller.

ding, the prerequisite being that the design should be technically simple, reliable and cost-effective. This led to the development of a welding head with a fixed focal point, which, as already noted, is essential to satisfactory weld quality. The first conceptual sketches of the proposed designs are reproduced in figure 9.

The design, which finally emerged, was the pressure-roller device (PRD) now used to weld the roof on the Volvo S80/V70, S70 and 850. The system features self-adjusting Z-compensation, which is provided by a telescopic mechanism incorporated in the head and requires only coarse programming of the weld geometry in the Z-direction (along the length of the car). The maximum compensation in this direction is 50 mm. The roller pressure, which is variable, is designed to apply a constant pressure to the roof panel, enabling the welding head to follow the panel contours accurately, regardless of deviations between the programmed welding path and the actual position of the roof. The focusing mirror is permanently attached to the

pressure roller mounting to maintain the focal point at an absolutely fixed position in the material.

Other flexible production tools, such as the pressure-clamping device (PCD) shown in figure 10, have been developed from the original PRD concept. The difference between the two systems is that, in the former case, the complete welding head moves continuously, together with the mechanical system, along the joint. In the PCD system, on the other hand, the welding head is traversed incrementally to selected welding positions, in which welding takes place with the robot at rest. In this case, the necessary movement is incorporated in the head and a random weld contour can be accommodated within the limitations of the moveable focusing head.

Panels for welding, including component variations

- Technical risks
- System engineering risks
- Economic risks High-quality laser weld.

Production at the Torslanda plant in Gothenburg

In view of the demand for greater flexibility, a system based on standard robots with articulated beam delivery [Fig. 11] has been chosen. The main system components are:

- two high power CO₂ lasers (6kW /5kW of type Rofin-Sinar/Trumpf);
- two 125 kg KUKA standard robots (on the left and right-hand side respectively);
- two Zeiss telescopic arms for the laser beams
- two welding heads similar to those used in the earlier installations;
- sensors for detecting the exact position of the roof panel (similar to the system at the Ghent plant).

The system offers a number of advantages compared with a conventional gantry system.

Conventional industrial robots (of similar type to those employed for spot welding in the adjoining stations) are used instead of a gantry-based system, which runs high volume production on roof laser welding since 1989 (Volvo 850,S70/V70) in Ghent. This means that the maintenance personnel are familiar with the equipment, eliminating the need for extra training or additional spare parts.

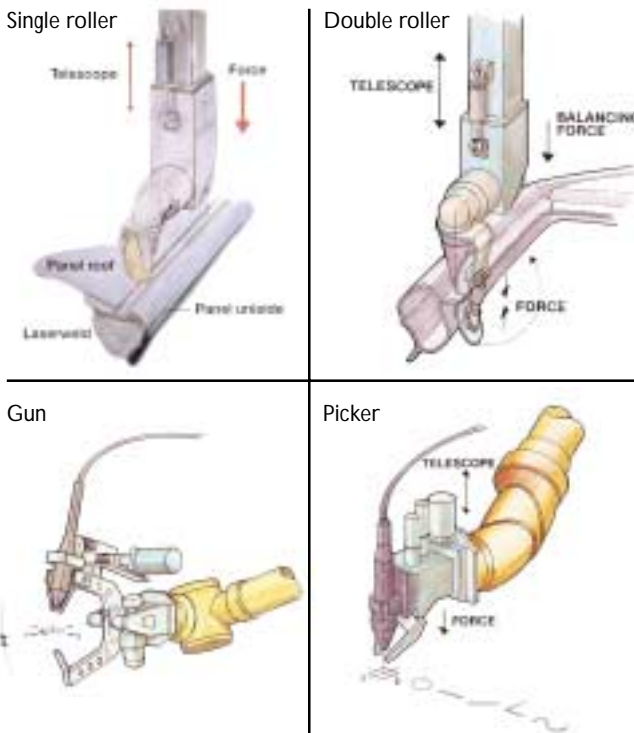


Figure 10. Welding heads based on PRD and PCD principles. The single-roller configuration is used to weld the Volvo S80, S70 and 850 roof.



Figure 11. Welding robot at Volvo's Gothenburg plant.

- Each robot can access both sides of the body, providing system redundancy. If one robot fails, production can be continued using the second machine until repairs are carried out.
- Production capacity can be expanded at relatively modest cost by installing a second laser source. Both sides of the body can be welded simultaneously and the cycle time shortened correspondingly when each robot is equipped with its own laser.
- If two lasers are installed, either one may be used by the two robots. As a result, if one laser becomes faulty, production can be continued using the other until the fault has been corrected (although the cycle time will be increased).
- The capital cost is approx. 25% lower than that of a conventional gantry robot.

Flexible body production

Through the market changes where customers ask for more differentiated products, models or variants, in a shorter period of time. Flexible body shops have emerged as the only answer to meet these targets. The definition of a flexible body shop for our purposes is shown in figure 12.

Different complete products as A, B, and C have to pass through the same investment with a variable product-mix. Investment-wise this flexibility has a level approximately 20% above the investment needed for traditional type-bound equipment for launching the first model. When another model is added, the overall average investment is much lower than for several type-bound body shops (both for equipment and engineering).

To reduce lead-time dramatically, the process development has to start already during the pre-production phase where product and type bound tooling are trimmed together under production requirements. Quality-wise, one numerical data base (NUFO

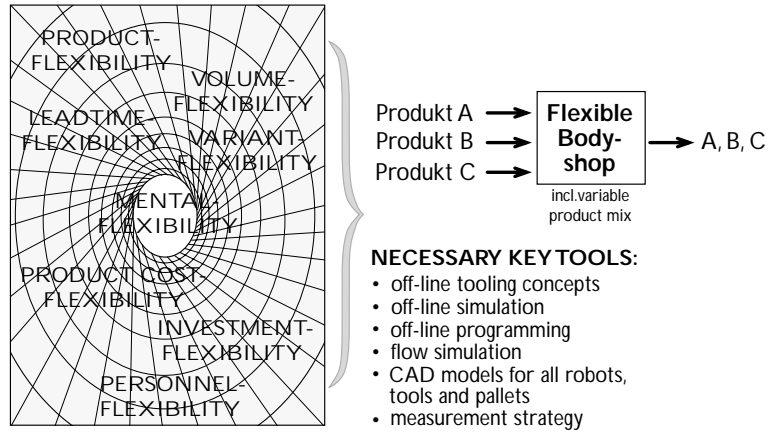


Figure 12. Flexible Body Production.

-base) is needed for both product and process equipment, instead of several physical models, as in the past, to reach the target values for the geometry of the complete car-body. The OFF-LINE Tooling concept with multi-tooling (pallets) is necessary in combination with an overall quality strategy through all the phases of the project. The robots as flexible tools in the body shop for different applications, (e.g. spot welding, laser-welding/cutting, sealing, gluing, stud welding and material handling), have to be programmed outside the production-line for different car bodies. This means a complete OFF-LINE programming strategy with automatic calibration-methods to minimise the lead-time necessary for launching the next car model or variant. OFF-LINE simulation of each station, in main line as well as subassemblies, supports robot programming regarding the accessibility to the product. Flow simulation of the whole body shop is needed to handle the logistic flows of pallets and material.

Multi-tooling versus single tooling has always been the main discussion in choosing the right technique for body shop equipment.

In the case of single tooling, the parts/products are

transported from station to station with individual tooling (type-bound) in each station. Tack welding has to be the first station before transportation, which is a great restriction in the layouts of the production lines. Moving a part from station to station is not good for the geometrical part stability = precision.

In the case of multi-tooling the parts/products are clamped in the fixture = pallet (type-bound) and moved together in clamped position from station to station. This kind of part-handling is good for the geometrical part stability = precision. Tack welding is not related to the first station and the concept gives the highest sequence-flexibility corresponding to the structures and layouts of the production-cells.

In the case of the flexible body shop VTK in Gothenburg, with multi-tooling, the functional target values for high precision from the product side are related to functional values:

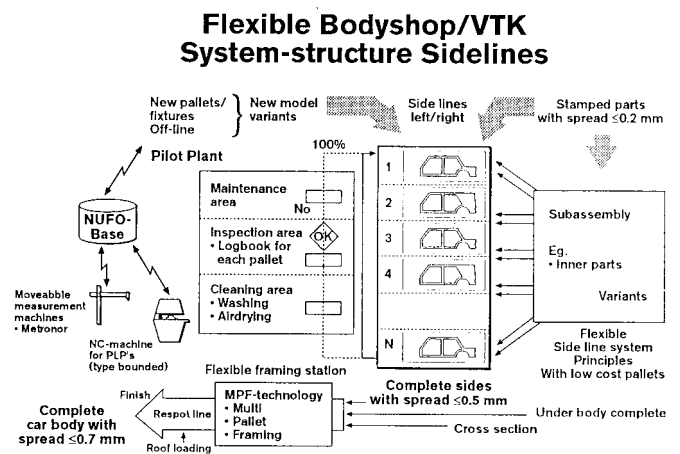


Figure 13. System structure guidelines.

- ≤ 0.2 mm spread in stamped parts
- ≤ 0.5 mm spread in pre assembled parts
- ≤ 0.7 mm spread in complete car bodies.

To reach these goals, all process equipment must be geometrically secured for high precision. The main principle is shown in figure 13, as an example in 'System-structure sidelines. The incoming materials to the pallet-based sidelines are stamped parts with a spread ≤ 0.2 mm, or subassemblies for variants. To minimise the spread of incoming material means in practice:

Higher demands on the coils from the steel suppliers (thickness, coating layers, strength, lead-time) Smaller batches to eliminate the temperature of the press dies.

All suppliers of press parts, as well as suppliers of subassemblies have to be quality secured.

The industrial system 'sidelines' has to make sure that complete sides with a spread ≤ 0.5 mm is the result of production.

This means a maximum additive spread of ≤ 0.3 mm between the input and output through this process and automatically gives the target values for the pallet accuracy. Part positioning in the pallets has to be within an absolute value of 0.3 mm in the volume of the whole pallet, including pallet fixation in the stations. Consequently a 3-2-1 system has to be used for parts (= product) and pallet-orientation. After producing the complete sides, the side pallets are

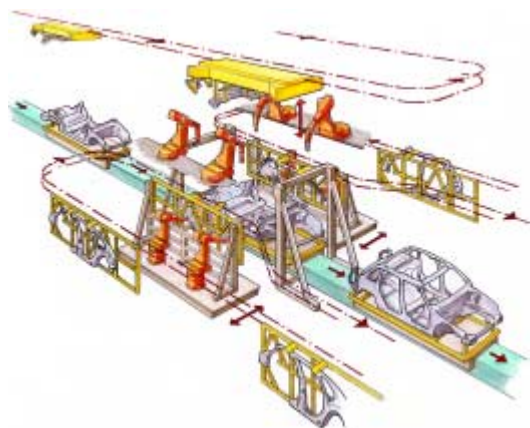


Figure 14. Pallet-flow of framing station.

mixed with an underbody pallet and a cross-section pallet without a roof in the flexible framing station using MPF- technology (MPF = Multi-Pallet-Framing) [Fig. 14 and 15]. The output of this station, the body-in-white, is geometry-wise ≤ 0.7 mm in spread, for functional values, before re-spot and finish line.

All pallets are scheduled to certain pallet-shops, one for each type (underbody, sides and cross-section pallets) for cleaning inspection and maintenance. Besides the functional tests of the pallets a geometrical test is done for each individual pallet with the numerical database (NUFO-base) as the reference. A logbook is needed for each pallet, and has to be updated according to a predetermined time-schedule. In the case of mechanical damage of the pallet, mainly standard elements above the pallet-frame will be destroyed. A new, complete, spare part will replace the old according to a modular system.

The mechanical spare parts are mainly manufactured in NC-machines with NUFO-base as the reference. All mechanical standard parts are plugged and screwed, which makes it possible to replace spare parts easily on the damaged pallet, without using shims. The critical interface between processequip- ment and product is related to reference pins, supports and the type bounded parts of the clamping devices. Both product and process-equipment are stored in the NUFO-base and can be checked together



Figure 15. MPF station.

OFF-LINE, in the pallet shops. Only 100% OK pallets, geometry- wise, are transported back in the flow of the production lines, otherwise bad quality will be produced.

In the past, quality control of the product was done mainly OFF-LINE in control fixtures or CMM:s (CMM= Coordinate Measuring Machines). In the production line, inspection systems such as Perceptron were used. These were more or less fixed installations, controlling a few critical requirements on the product.

The result was relative values, very hard to track back to the numerical product definition. In the case of inferior quality, the parts had to be scrapped or repaired before using it as an OK part.

One strategic point of view states: "If the incoming material is stable within accepted spread and when the process-equipment is in 100% good condition, then the product produced has to be OK". From this statement following options can be derived:

- The need of product measurement can be held at a minimum.
- Higher demand on equipment geometry control.

In practice the above strategic point of view can't be driven to its extreme, due to restrictions in real life.

For the Volvo S80/V70 production (and earlier Volvo S70/850), IN-LINE measurement machines with high programmable flexibility has been installed in the production line. Together with a lot of effort put in statistical analysis packages and programming tools, we now have improved the possibilities to monitor the product quality in "real time".

This gives unique possibilities to react fast on problems and to instantly cover current problem areas with relevant measuring.

The need of IN-LINE measurement machines is due to:

- Statistical process control in "real time".
- In full production, the stations are not accessible for equipment geometry measurements. This leads to low frequency in station geometry control.
- To qualify process and parts stability when modifying the product and during the ramping-up phases in production.
- Measuring of parts-systems on request from the final assembly plant for analysis of assembly problems.

The OFF-LINE tooling possibility, outside production lines, makes it easy to manufacture and verify new pallets (= moving fixtures) in the pilot plant for new car models and/or variants. Timesaving is the most important benefit when product and process- equipment are modified completely to a 100% quality in the early stages of car model projects. Standard techniques in machining in combination with CAD- technologies make it possible to manufacture several pallets with equally high precision.

During the years of 1990-1992, before the project start of the flexible body shop, the development of metrology methods with the Norwegian company Metronor A/S was done to improve assembly fit and finish in body-in-white. The evaluation of the

metrology system was focused on equipment measurement in the existing current Volvo 900-serie's production lines with extremely positive results. A feasibility study gave the following results.

- Identification of measurement-system requirements:
 - Transportability
 - Factory floor robustness
 - Set-up time
 - Set-up flexibility and accessibility
 - Minimal impact on production equipment.
- Systematic and comprehensive testing.

- Successful use of closest points functionality on manufacturing equipment.
- Practical use of CAD data on shop floor level.
- Demands for high precision metrology concept for large volumes, both for the use with pallets and in assembly stations.
- After this feasibility study the decision was taken to develop all procedures for the flexible mainline equipment measurements (Product: Volvo 850 and the successor models S70, V70 and S80).



Figure 16. Flexible door assembly station.



Figure 17. Flexible hood assembly station.



Figure 18. Flexible fender assembly station.

- Coordinate systems' linearity:
 - Factory coordinate systems
 - Station coordinate systems
 - Car coordinate systems (equipment alignment)
 - Part coordinate systems
 - Steering locator coordinate systems
 - Internal equipment geometry
 - Steering locator verification and adjustment.

In combination with the purchase of three high-precision, transportable, real-time photometry systems training of six operators (jig mechanics) was initiated, for the complete project. These operators worked as rotating teams with the three main suppliers (KUKA, Renault Automation and Volvo Olofstroem), using the MNS system for the complete new flexible body shop, at site, during the manufacturing of the process- equipment (pallets, main-stations and sub-assembly stations) prior to shipping. Geometry quality assurance and preliminary acceptance test was done at the suppliers' site. After shipping and complete final installation of the flexible body shop in Gothenburg, final acceptance was done with the same NMS method, in very short time, using NUFO-base as the master. Scheduled measurements OFF-LINE, mentioned above, are also performed, using the measurement method.

Materials flexibility for hang-on parts

In the flexible body shop VTK/Gothenburg all hang-on parts are automatically assembled by robots a complete modules in the main assembly line. Each mechanized station can handle the same type of module with different material as steel or aluminum and they could be mixed 1:1 re to different car models [Fig. 16,17 and 18], at present time the S80 and V70.

The tailgate of the V70 model is mounted as a complete painted supplier unit in the final assembly shop.

Conclusion

The complexity of new car body concepts to meet customer demands, clearly calls for the necessity of a concurrent engineering approach. The best properties can only be achieved if the choice of materials, body concept and joining methods is done in an integrated process.

For future body structures, all joining techniques have to be considered, and the optimum choice had to be made based on the required performance, such as fatigue behaviour, crashworthiness etc. Reliable tools for joint simulations must also be available and used already in the design phase of a new vehicle project. Together with results from experimental testing, design and manufacturing engineers are given the preconditions to create car body solutions of superior quality.

The results presented in this paper can be summarized as below:

- By introducing various grades of high strength steels and aluminium, it is possible to upgrade car body properties without adding a severe weight penalty.
- On complete car body level, it is possible to predict the fatigue behaviour of each single spot and arc weld in the structure.

- Through fairly small engineering steps it is possible to achieve significant increase in the global torsion stiffness of an estate car body
- Laser welding is today a mature technique and will be treated as an accepted production tool in relation to conventional joining techniques.
- Laser technology in the BIW shop has a considerable potential. Roof welding is only the first application and others will follow.
- Type specific invest for inspection jigs can be reduced up to factor 10.
- Considerable lead-time reduction for product development and manufacturing process.
- Improved measuring capability and flexibility.
- Flexible mechanized hang-on parts assembly in main line established.
- Car No.1 with customer quality in final product [Fig.19].
- Structured feed-back of the process capability into the product development phase.
- The launch of a second car model while producing an earlier introduced one (S80 and V70 in the same assembly line).

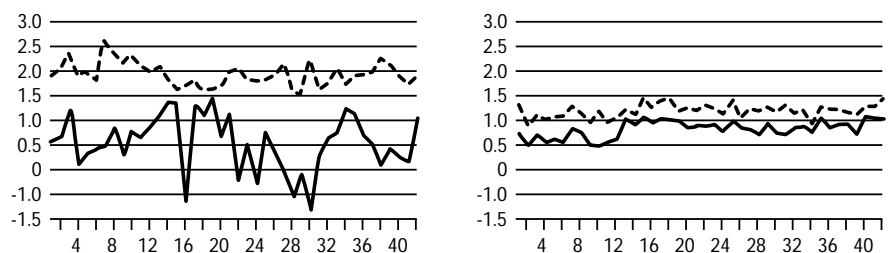
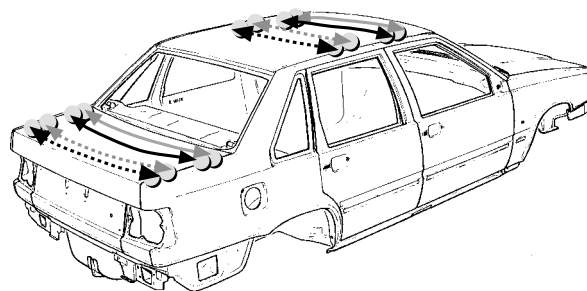


Figure 19. Process control

About the authors

Lutz Hanicke received his M.Sc. in Electrical Engineering from the University of Hannover in 1964. Between 1964-1984 he was employed at Siemens R&D, working on numerical controllers, robot and programmable logic controller techniques. He was later responsible for factory automation projects in steel, food and automotive industries, including marketing. He has been with the Volvo Car Corporation since 1984. As head of research and development for laser technologies at the Manufacturing Engineering Department, he won the Volvo Technology Award in 1993 for his development of roof laser welding in series production. He has also been heavily involved in flexible body production including prototyping and measurement methods for high body accuracy. After 5 years in the vehicle concept group, where process driven design was one of the key areas, he is now back in the Product & Process Development area as senior project manager.

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Johnny K Larsson graduated from the Technical University of Lund, Sweden in 1975. After spending eight years as an engineer in heavy truck industry, he joined Volvo Car Corporation in 1986. Since then he has been responsible for the R&D programme of the Body Engineering Department, covering areas such as materials technology, joining methods, structural analysis and simulations.

Through the years Mr. Larsson has presented a number of technical papers focusing on the innovative research work performed within the Volvo group.

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Martin Weiman received his M.Sc. in Civil Engineering from the Chalmers University of Technology (Gothenburg) in 1994. He started working for Volvo Car Corporation in 1995 and joined the company in 1996. He has mainly been working with structural matters such as stiffness, fatigue and crash for both previous products as well as the new P2 products. During 1999-2000 he has been project leader for the rear floor body structure in a new car project.

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References

- [1] Larsson, J.K., "Body-in-White - No Longer Just a Subject on Spot Welding", Proceedings of the XXVI FISITA Congress, Prague, June, 1996
- [2] Larsson, J.K., "A Concurrent Approach to Body-in-White Joining Technologies - The Introduction of High Quality, Cost Effective Methods into Running Production", Proceedings of 32th ISATA Conference, June, 1999
- [3] Hanicke, L. and Strandberg, -, "Roof Laser Welding in Series Production", SAE-paper 930028
- [4] Hanicke, L. and Nilsson, L., "High Precision in Car Body Manufacturing", SAE-paper 950573
- [5] Hanicke, L., Haller, R. and Hogstrom, P., "Body and Component Accuracy in Assembly Systems", SAE-paper 982269:
- [6] Larsson, J.K. and Hanicke, L., "Multi-material Approach with Integrated Joining Technologies in the New Volvo S80", SAE-paper 1999-01-3147

Pressrelease

Nyhet – 5-axligt 3D lasersystem för skärning och svetsning från NTC – nu i Sverige

NTC - Nippei Toyama Corporation, Japan, världen största tillverkare av 5-axliga lasersystem för tredimensionell bearbetning finns nu på svenska marknaden.

Första maskinen i Sverige, en TLM 610 har levererats till Tryckta AB i Markaryd. Systemet är utrustat med Fanuc CO₂ laserkälla på 3000 watt och försedd med palettväxling. Det totala arbetsområdet är 3 100 x 1 900 x 600 mm.

TLM-serien är av portaltyp och finns som standard i flera storlekar med arbetsområde upp till 4 300 x 2 800 x 1 000 mm. Den levereras med styrsystem och CO₂ laserkälla från Fanuc upp till 6000 watt.

Genom sitt stora arbetsområde kombinerat med överlägsen stabilitet och noggrannhet har NTC stora framgångar som leverantör till bilindustrin i Japan och USA. Enbart inom Detroit-området finns i dag mer än 100 lasersystem från NTC i produktion.

Det speciella med NTC's 3D-laser, förutom den stabila konstruktionen, är det patenterade laserhuvudet som alltid, i alla rörelser, rör sig kring en fast NOLLPUNKT vilket möjliggör skärning med mycket hög precision. Representant för NTC i Sverige är Mapro LaserSystem AB i Växjö och Halmstad.

www.mapro-laser.se



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Välkommen till

LASERDAGEN II den 26 oktober 2000

På Gnosjöandans Kunskapscentrum i Gnosjö och LaserCentrum i Gnosjö AB

Program

09.30 Samling på Gnosjöandans Kunskapscentrum (GKC), Fritidsvägen 4 i Gnosjö

Registrering, kaffe
Per Westerhult, VIBAB/Lasergruppen

09.50 Välkomsthälsning
Johnny K. Larsson, Volvo Personvagnar AB (Ordförande i Lasergruppen)

10.00 Nya koncept för lasermärkning
Tore Salmi, Permanova Lasersystem AB

10.40 Skärgaser för modern produktion
Bo Williamsson, AGA Gas AB

11.20 Resultat från RACER-programmet
– Laserbearbetning och abrasiv vattenstråleskärning
Hans Engström, Luleå Tekniska Universitet

12.00 Lunch på Töllstorpshallens Veranda (c:a 50 m promenad från GKC)

13.00 Nya koncept och produkter från Trumpf/Haas Laser
Thomas Hägglund, Trumpf Maskin AB

13.40 Erfarenheter vid lasersvetsning med CO₂ laser
Bengt Johansson, LaserCentrum i Gnosjö AB

14.10 Presentation av LaserCentrum i Gnosjö AB
Stefan Bengtsson, LaserCentrum i Gnosjö AB

14.20 **Transport till LaserCentrum i Gnosjö AB**

14.40 Verkstadsvisning
Bengt Johansson, LaserCentrum i Gnosjö AB

15.30 Kaffe och frågestund

16.00 Avslutning

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