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MTT Manufacturing Technology Today

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Central Manufacturing Technology Institute

X-Ray Inspection System

Key Features

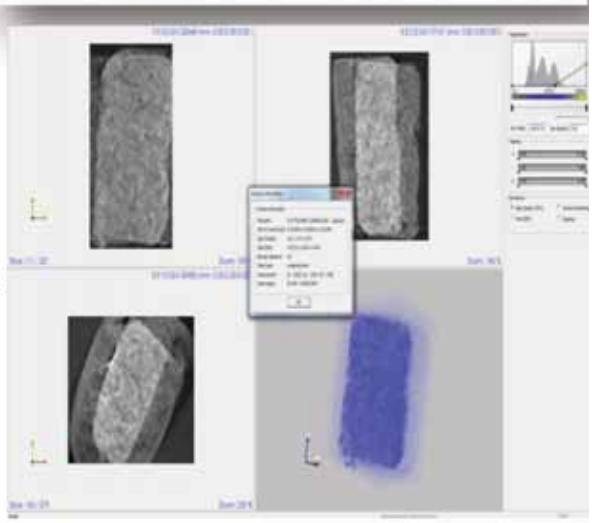
- Geometric Magnification –2000X
- Feature Detectability down to 500nm
- Sample Size inspection – 500mm X 500mm
- 160KV/20W Tube Power
- Capable of 3D CT (Tomography)

Applications

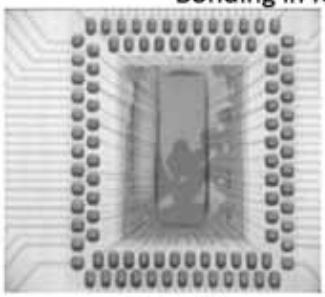
- MEMS/ IC Packaging (For Failure Analysis) – Inspection of devices after Die Attach, Wire bonding, Encapsulation for voids, wire sweeps and any internal defects
- Inspection of hidden defects in thin casting parts and tear down of components in a packaged electronic devices.
- Inspection of PCB defects – Voids, Cracks
- Inspection of small concrete slabs for analysis of hydration effect.

Inspection of Wire Bonding in IC

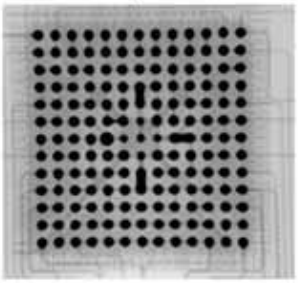
Pulp Cavity Inspection in Tooth



Calculation of Void Percentage in Small Concrete mortar using Tomography



Die Voids



Inspection of BGA Solder Balls

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Contents

Technical Papers

Manufacturing Technology Today (MTT) Journal hosted Online @ "i-Scholar" digital library
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Manufacturing Technology Today (MTT) (ISSN: 0972-7396), a monthly technical journal from Central Manufacturing Technology Institute (CMTI), is in the 16th (Sixteenth) year of publication.

The journal covers technical articles/papers, manufacturing technology abstracts, patent abstracts, calendar of forthcoming events, technology trends in manufacturing related areas, select bibliographies on subject and standards, vintage machine, IPR related information.

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DEVELOPING EMPIRICAL RELATIONSHIP TO PREDICT THE DIAMETER OF MULTIWALL CARBON NANO TUBES (MWCNTs) SYNTHESIZED BY CHEMICAL VAPOR DEPOSITION (CVD) PROCESS

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Abstract: *The thermal chemical vapor deposition (CVD) route was used to synthesize multi walled carbon nano tubes (MWCNTs) and metal NiO powders was used as catalyst and it supported on crystalline alumina nano particles. Acetylene was used as the carbon source gas and Argon was used as the carrier gas. An empirical relationship was developed to predict the diameter of MWNTs incorporating important CVD process parameters. Three factors, five levels central composite design was used to minimize number of experimental conditions. The CVD parameters such as reaction temperature, gas flow rate and process time were chosen as the important parameters. The diameter of MWNTs was measured using field emission scanning electron microcopy (FESEM). Analysis of variance (ANOVA) method was used to identify significant main and interaction factors. Final empirical relationship was developed using these significant factors. The developed empirical relationship can be effectively used to predict the diameter of MWNTs synthesized through CVD process at 95% confidence level.*

Key words: *Carbo Nano Tube, Chemical Vapor Deposition, Design of Experiments, Analysis of Variance*

1. INTRODUCTION

The "NanoTechnology" field is growing up very fast to miniaturize the bulk things to nano level product and it is known as the molecular building. In the field of nanotechnology, world criticize mainly on the CNTs (Carbon NanoTubes); because science behind the CNTs growth are still a mystery to the world. The carbon nanotubes are the allotropes of carbon, which has cylindrical structure, were diameter in nm. CNTs extraordinary thermal, mechanical and electrical properties led researchers to create new novel process to synthesis the CNTs (Iijima, 1991). There are two types of CNTs, Single walled carbon nano tubes (SWNTs) and Multi walled carbon nano tubes (MWNTs).

Iijima shown the importance of carbon nano tubes to the scientific world and also proved the statement of the Richard Feynman "There's Plenty of Room at the Bottom". It is very important for the use of CNTs to prepare CNTs in large scale and ideal quality. Up to now, CNTs have been produced by various kinds of methods, mainly including arc discharge, laser ablation, and CVD. Compared with the other two methods, CVD is considered as the most promising method for easily scaled-up to batch-scale production due to simplicity and economy. The CVD methods are attractive because of their effectiveness in generating carbon feedstock and the straight forward scale up. Furthermore, it could be possible to achieve different types of CNTs by controlling various set of process parameters (Kong.et.al, 1998).

Several factors may influence the CNTs like reaction temperature, process time, catalyst morphology and flow rate of precursor gas. The factors influences on the morphology of the CNTs have been studied by the several researchers around the scientific world. The past factor studies, researchers used conventional techniques to study the control of these parameters on the growth of CNTs by varying one parameter while keeping other parameters constant. This method of study has several disadvantages. For example, this technique ignores the interface effects between the parameters, leading to inaccurate predictions of the optimal conditions. In addition, these methods require a large number of experiments and are time-consuming.

Response surface methodology (RSM) can avoid the limitations of conventional methods and is commonly used in many fields. The main purpose of RSM is to check the optimum operational conditions for a given system or to determine a region that satisfies the operational specifications (Montgomery et al. 2000). The authors (Liu. et.al, 2011, C.N.He, 2010, Nourbakhsh, 2006) have studied the influence process parameters on yield, morphology and length of CNTs but very few researches have carried out research to study the influence of CVD process parameters, on the diameter of MWCNTs.

Therefore, the main focus of this paper is to develop an empirical relationship to predict the diameter of the MWCNTs by the statistical design of experiments (DOE). A standard design called a central composite design (CCD) was selected to simultaneously study the effects of reaction temperature, process time and flow rate of precursor gas on the mean diameter of the carbon samples. Empirical relationship correlating these preparation variables (reaction temperature, process time and precursor gas flow rate) to the response (mean diameter of MWCNTs) was then developed.

2. EXPERIMENTAL

The experimental work was divided into five consecutive parts as follows

(i) Identify important CVD parameters and their levels.
(ii) Prepare catalyst.
(iii) Synthesize MWCNTs by CVD process.
(iv) Purify of MWCNTs by wet chemistry method.
(v) Measuring the average diameter of MWCNTs.

The above five sequential steps were followed by almost 80% of researchers who working on the optimization conditions in field of Carbon nano tubes (CNTs) studies.

2.1 Identify Important CVD Parameters and their Levels

From the literature (2-5), it was identified that (i) reaction temperature (ii) precursor flow rate (iii) process time are the predominant influencing yield and morphology of CNTs. From the trial experiments, the feasible working ranges of CVD parameters were identified and they are shown in table 1.

Generally, the central composite design (CCD) consists of 2^n factorial runs with 2n axial runs and n_c centre runs (six replicates). For each categorical variable, a 2^3 full factorial CCD for the three variables, consisting of eight factorial points, six axial points and six replicates at the centre points was employed; indicating that altogether 20 experiments were required, as calculated from Equation (1):

$$N = 2^n + 2n + n_c = 2^3 + 2 \times 3 + 6 = 20 \text{ ----------(1)}$$

Where N is the total number of experiments required and n is the number of variables.

The table 2 shows the design matrix of

Table 1: Important CVD Process Parameters and their Levels

No	Parameter	Notation	Unit	Levels				
				-1.682	-1.0	0	-1.0	1.682
1	Reaction Temperature	T	◦C	732	800	900	1000	1068
2	Flow Rate of Precursor Gas	F	ml/min	106	120	140	160	174
3	Process Time	P	mins	8	15	25	35	42

Table 2: Experimental Design Matrix and the Results

Experimental Number	Coded Values			Actual Values			Average Diameter of MWCNTs (nm)
	T	F	P	T (◦C)	F (ml/min)	P (mins)	
1	-1.00	-1.00	-1.00	800	120	15	29
2	1.00	-1.00	-1.00	1000	120	15	23
3	-1.00	1.00	-1.00	800	160	15	31
4	1.00	1.00	-1.00	1000	160	15	39
5	-1.00	-1.00	1.00	800	120	35	22
6	1.00	-1.00	1.00	1000	120	35	17
7	-1.00	1.00	1.00	800	160	35	27
8	1.00	1.00	1.00	1000	160	35	35
9	-1.682	0	0	732	140	25	31
10	1.682	0	0	1068	140	25	33
11	0	-1.682	0	900	106	25	15
12	0	1.682	0	900	174	25	32
13	0	0	-1.682	900	140	8	33
14	0	0	1.682	900	140	42	24
15	0	0	0	900	140	25	32
16	0	0	0	900	140	25	34
17	0	0	0	900	140	25	33
18	0	0	0	900	140	25	31
19	0	0	0	900	140	25	32
20	0	0	0	900	140	25	33

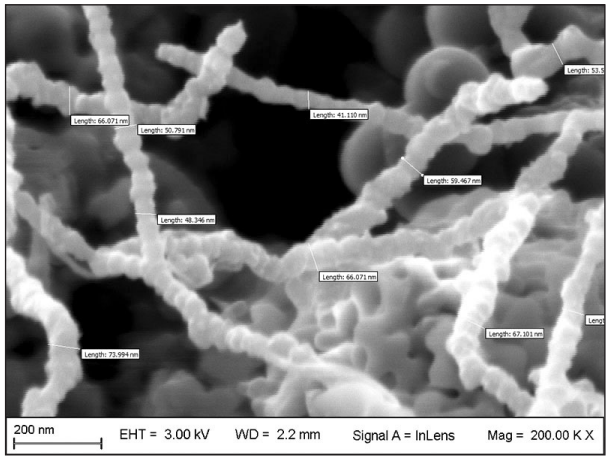
experimental coded values, actual factors and the results. The centre points were used to determine the experimental error and the reproducibility of the data. The independent variables were coded to the (−1, 1) interval where the low and high levels were coded as −1 and +1, respectively. The axial points were located at (±1.682, 0, 0), (0, ±1.682, 0) and (0, 0, ±1.682) where 1.682 is the distance of the axial point from the centre and makes the design rotatable.

2.2 Prepare Catalyst

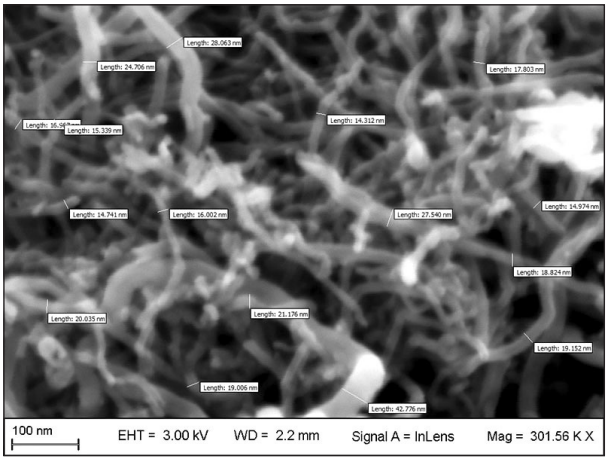
The second step of the experimental condition is to prepare the amount of catalyst according to number of experiments and catalyst loading. The NiO catalyst was prepared by impregnate 1 g of fumed- alumina _Degussa, 100 m^2/g surface area Nano particles with 30 ml of a methanol solution that contains 0.245 g of Ni $(No_3)_2$. $6H_2O$. The impregnation typically lasts for 1 h at room temperature. The methanol solution was then removed via rotary evaporation at 80°C. The material is then heated at 150°C overnight followed by grinding into a fine powder. This resulting catalyst is denoted as NiO/alumina. In this work, the (metal-mol)/ (alumina weight) ratio is 0.6 mmol/g (Kong.et.al, 1998, Makris.et.al, 2004).

2.3 Synthesize MWCNTs by CVD Process

The MWCNTs were synthesized at atmospheric pressure in a quartz tube reactor (Diameter: 70 mm, Length: 300 mm) by thermal chemical vapor deposition machine. The MWCNTs synthesis was carried out under the reaction conditions



(a) Experiment No.4



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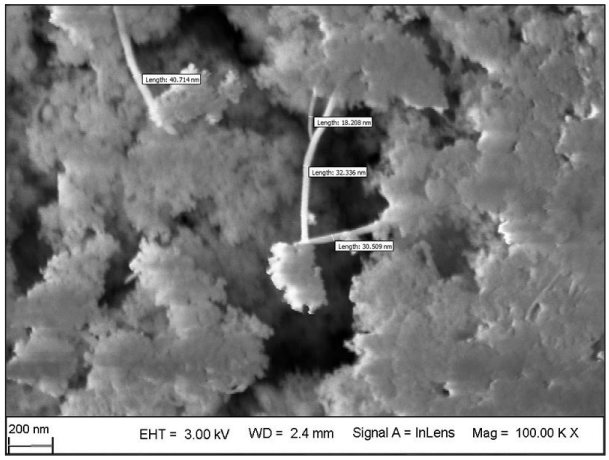
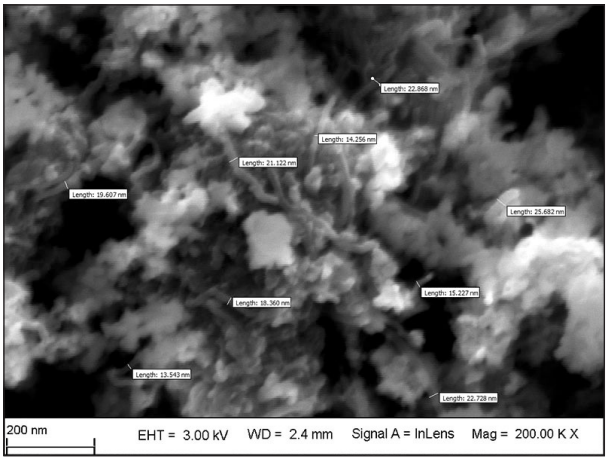


(c) Experiment No.8



(d) Experiment No.11

Fig 1. FESEM Image of MWNTs

according to the Table 2. In these experimental conditions, the catalyst loading (10 mg) and carrier gas (Argon: 100 ml/min) flow rate were kept constant. The catalyst was loaded into centre of the hot zone reactor and argon (100 ml/min) was switched on until reaching reaction temperature and then argon is switched off then replaced by the carbon precursor (acetylene) to flow to the reaction zone according to the process time and acetylene was replaced by argon until furnace reaches room temperature. The carbon samples along with catalyst particles were collected from the quartz tube for the purification process to remove amorphous carbon and catalyst particles.

2.4 Purification of MWCNTs by Wet Chemistry Method

After CVD process the samples were purified by three steps first, acid treatment, sonication and filtered with sintering ceramic crucible. In an acid treatment, the samples were stirred in nitric acid for three hours in room temperature. In this process of acid treatment to the carbon diffused samples, metal content would be dissolved in the acid but CNTs withstand the strong acid attack. After acid treatment, the metals (Catalysts particle) and amorphous carbon products were dissolved in acid solution due to the acid attack. The crystalline carbon products are free from catalyst materials. The crystalline carbon samples were introduced to sonication by dissolving carbon products (samples) into the ethanol solution and sonicated for 10 mins. In this process the agglomerated particles separated and finally ethanol was filtered by using sintering ceramic crucible and the collected Carbon products were dried in furnace. Finally, the samples are sent to characterization techniques.

2.5 Measuring the Average Diameter of MWCNTs

The MWCNTs synthesized by chemical vapor deposition process were characterized by the

field emission scanning electron microscopy (FESEM) technique. FESEM images of MWCNTs synthesized using various combination of CVD parameters are shown in Fig.1, diameter of MWCNTs was measured using image analysis software at 10 locations and average diameter is presented in Table 2.

3. DEVELOPING EMPIRICAL RELATIONSHIP

The characterization of carbon samples were analyzed by using Field emission scanning electron microscopy techniques (FESEM). The diameters of MWCNTs were measured using FESEM images for the 20 experimental conditions and the mean diameter was calculated. The obtained responses were incorporated into the design matrix (Actual: Table 2) to develop an empirical relationship. The evaluation of model f(x) is analyzed by selecting the quadratic order and polynomial model.

To correlate the CVD parameters and average diameter of MWCNTs, a second order quadratic model was developed. The response 'D' (average diameter of MWCNTs) is a function of temperature (T), flow rate (F)and process time (P). Hence it can expressed as,

$D = f\{T, F, P\}$----------(2)

An empirical model was developed for each response that correlated it to the CNT production variables using a second-degree polynomial equation as given by Equation (3):

$$Y = b_o + n\sum_{i=1} b_i x_i + \left(\sum_{i=1}^{n} b_i x_i\right)^2 + \sum_{i=1}^{n-1}\sum_{j=1}^{n} b_{ij} x_{ij} \quad \text{---(3)}$$

Where Y is the predicted response, b_0 is the constant coefficient, b_i is the linear coefficients, b_{ij} is the interaction coefficients, b_{ii} is the quadratic coefficients and x_i, x_j are the coded values of the MWCNTs production variables.

For three factors, the selected polynomial could be expressed as

$$D = \{b_o + b_1(T) + b_2(F) + b_3(P) + b_{12}(TF) + b_{13}(TP) + b_{23}(FP) + b_{11}(T^2) + b_{22}(F^2) + b_{33}(P^2)\}\ nm \quad \text{----------(4)}$$

Where b_o is the average of response (mean diameter) and $b_1, b_2, b_3, b_{12}, b_{13}, b_{23}, b_{11}, b_{22}, b_{33}$ are the coefficients that depends on their respective main and interaction factors, which were calculated using the expression given below,

$b_i = \Sigma(X_i, Y_j)/n$----------(5)

Where 'i' varies from 1 to n, in which Xi is the corresponding coded value of a factor and Yj is the corresponding response output value (mean diameter) attained from experiment and 'n' is the total number of combinations considered. All the coefficients were calculated by applying central composite face centered design using the design expert statistic software package. The significance of each co-efficient was calculated by students t-test and p-values, which are presented in table 3; value of "Prob>F" less than 0.05 indicate that the model terms are significant. After determining the significance coefficients (at 95% confidence level), the final relationship was developed by using these coefficients. The final empirical relationship derived by the above method, to estimate the mean diameter of MWCNTs synthesize by CVD process.

The Model F- value of 137.93 implies the model is significant. There is only a 0.01% chance that a "Model F- value" this large could occur due to noise. Values of "Prob>F" less than 0.0500 indicate model terms are significant. In this case $T, F, P, TF, TP, T^2, F^2, P^2$ are significant model terms. Values greater than the model terms are not significant. If there are many insignificant model terms (not counting those required to support hiearchy), model reduction may improve our model. The "Pred R-squared" of 0.9848 is in reseasonable agreement with the "Adj R-squared" of 0.9863.

The final empirical models of the three responses, in terms of the coded factors for the mean diameter, have shown in the equation 6.

Mean Diameter of MWCNTs = $(32.50+0.61\ T) + (5.10F) - (2.65P) + (3.37TF) + (0.12TP) + (0.62\ FP) - (0.15T^2) - (3.15F^2) - (1.38P^2)$ --------(6)

Where T is the coded value of the reaction temperature, F is the coded value of the Flow rate of Precursor gas and P is the coded value of the Process Time. A positive sign in front of the terms indicates synergistic effect, whereas a negative sign indicates an antagonistic effect.

The fig.2 obtained from (design of experiment) analysis. The color rectangular boxes is denotes the standard experiment run. (a) Were the temperature increases from 700 to 1000° C the mean diameter of the MWNTs were decreased

Table 3: Analysis of ANOVA for Response Surface Quadratic Model for Mean Diameter

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	710.48	9	78.94	137.93	<0.0001 significant
T- Reaction Temperature	5.12	1	5.12	8.95	0.0135
F-Flow rate	354.61	1	354.61	619.60	<0.0001
P-Process Time	95.62	1	95.62	167.07	<0.0001
TF	91.13	1	91.13	159.22	<0.0001
TP	0.13	1	0.13	0.22	0.6503
FP	3.13	1	3.13	5.46	0.0416
T^2	0.31	1	0.31	0.53	0.4819
F^2	143.06	1	143.06	249.98	<0.0001
P^2	27.56	1	27.56	48.16	<0.0001
Residual	5.72	10	0.57		
Lack of Fit	0.22	5	0.045	0.041	0.9984 not significant
Pure Error	5.50	5	1.10		
Corrected total	716.20	19			
Std. Dev.	0.76				
Mean	29.30				
C.V. %	2.58				
R-Squared	0.9920				
Adj R-Squared	0.9848				
Pred R-Squared	0.9863				
Adeq Precision	44.456				

df: degrees of freedom; CV: coefficient of variation; F: Fisher ratio; p: probability

due to higher carbon diffuses towards the catalyst particles and also the agglomeration of catalyst particles at higher temperatures results to the smaller diameter tubes (Poro.et.al 2010). Further increasing from 1000 to 1100° C, the catalyst particles leads to over agglomerated and forms bulk particles lead to formation of amorphous carbon on the catalyst surface. (b) The mean diameter of MWCNTS increases, while flow rate of acetylene increases from 100 ml/min to 160 ml/min, further increases of flow rate from 160 to 180 ml/min, decreases the mean

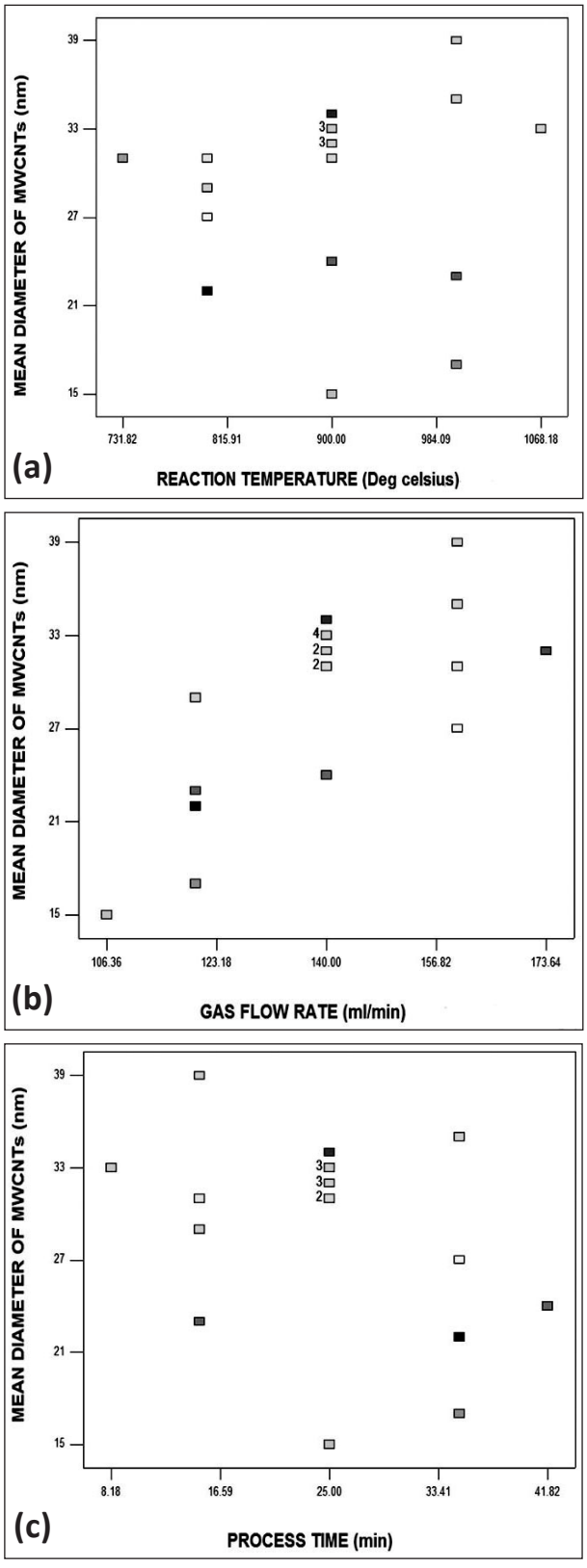


Fig 2. The Graph Represents (a) the Influence of Growth Temperature in MWNTs Mean Diameter. (b) The Influence of Flow Rate in MWNTs Mean Diameter. (c) The Influence of Process Time in MWNTs Mean Diameter.

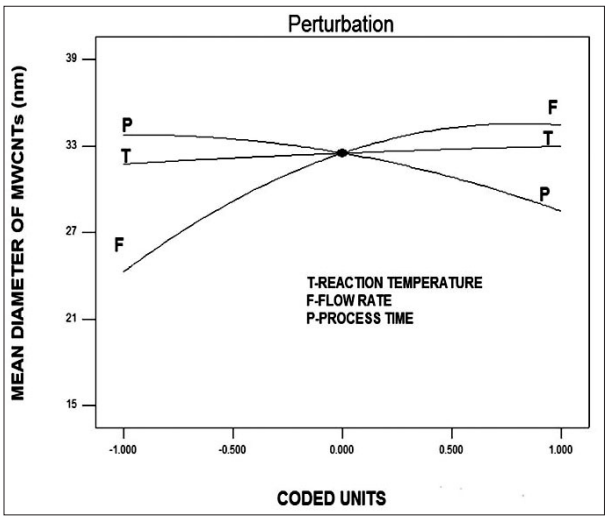


Fig 3. Perturbation Graph

diameter, due higher carbon atoms diffuse towards catalyst particle leads to amorphous carbon formation. The effect was clearly evident in the fig.1 (d), were the flow rate of 160 ml/min very high for 1000° C (Zhangyi.et.al 2007). (c) The influence of process time on mean diameter of MWCNTs was obtained from the graph column analysis. The mean diameter decreases with increase in process time. Above certain process time the excess carbon atoms diffusion leads to amorphous structure, clearly evident in fig.1 (c).

4. EVALUATING THE INTERACTION EFFECT OF FACTORS ON RESPONSE

The perturbation plot helps to compare the effect of all the factors at a particular point in the design space. The steep slope or curvature in a factor shows that the response is sensitive to that factor. A relatively flat lines shows insensitivity to change in that particular factor. The fig.3 shows the perturbation graph for mean diameter of MWCNTs and its interaction effect with process factors. The perturbation plots of the responses are presented with the purpose of understanding the main and interaction effects of each factor, considering the full quadratic model. The average diameter has been plotted as a function of the normalized independent variables. It has been demonstrated that the factor flow rate has the most significant effect on the mean diameter of MWCNTs. However, the effects of the temperature and process time were also found to be significant.

5. CONCLUSIONS

1. An empirical relationship was developed to predict the mean diameter of MWCNTs

synthesized via CVD process. The relationship was developed by incorporating CVD process parameters (reaction temperature, flow rate of precursor gas, process time) and the response, mean diameter of MWCNTs.

2. From the ANOVA results, it is found that the flow rate of precursor gas is having more significant effect (F=619.60) and reaction temperature is having a less significant effect (F=8.95) on mean diameter of MWCNTs.
3. Minimum mean diameter of MWCNTs 15 nm was obtained under the test conditions of reaction temperature 900° C, 100 ml/min flow rate, 25 mins process time and maximum mean diameter of MWCNTs 39 nm was attained under the test conditions of reaction temperature 1000° C, 160 ml/min flow rate and 15 mins process time.

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NOTCH TENSILE PROPERTIES OF VARIOUS REGIONS OF DISSIMILAR JOINTS OF AUSTENITIC AND FERRITIC STEELS

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Abstract: *In sodium cooled fast breeder reactor at Kalpakkam, the steam generators are constructed using modified 9Cr-1Mo (also called as Grade 91 or P91) ferritic steel because of its high temperature strength and resistance to stress corrosion cracking. The interconnecting sodium piping between reactor and steam generator is made up of AISI 316LN because of its high creep strength and corrosion resistance. Nickel based fillers (Inconel 82/182) are commonly used to weld the 316LN piping with steam generator. For a better structural integrity assessment of this dissimilar joint, the tensile properties of each region need to be evaluated. Evaluating the tensile properties of various regions by smooth tensile specimens is quite complex and time consuming. In the present investigation, the notch tensile properties of various regions were evaluated by placing a notch at the desired locations of the dissimilar metal weld joint (DMWJ). The dissimilar joint between P91 and 316LN is fabricated by manual metal arc welding (MMAW) process using Inconel 182 electrodes. Notch tensile properties of each region were evaluated by placing a notch at different locations (viz. weld metal, buttering, HAZ of P91 and HAZ of 316LN). Microhardness variation across the DMWJ was recorded. Microstructural features of various regions were characterized by optical and scanning electron microscope. From this investigation, it is found that the notch placed in the HAZ of P91 exhibited highest notch tensile strength than other regions. A non-uniform hardness distribution is observed across the DMWJ and the maximum hardness is recorded at the interface between P91 HAZ to Inconel 182 buttering. The hardness is minimum at the outer edge of HAZ of P91 side. Evolution of carbon enriched hard zone at the interface between P91 and Inconel 182 buttering could be the reason for highest notch tensile strength.*

Keywords: *Dissimilar Metal Weld Joint, Notch Tensile Test, Microhardness, Microstructure*

1. INTRODUCTION

In fast breeder reactors, modified 9Cr-1Mo ferritic steel (also call as Grade 91or P91) is used to fabricate steam generators (SG's) due to its high temperature strength, stress corrosion cracking resistance and adequate creep strength. Whereas austenitic stainless steel (Type 316LN) is a major structural member for Intermediate Heat Exchanger (IHX). Therefore, dissimilar metal weld joint (DMWJ) between these materials are unavoidable. Earlier, ER 308L and ER 309L stainless steel electrodes were used to join these materials but resulted in premature failures due to thermal stress mismatch, carbon migration and sigma phase formation. To overcome these problems, Nickel based (Inconel 82 and Inconel 182) consumables are used because the thermal expansion of this material (15.5 μm/m/°C) lies in-between to the P91 (12.8 μm/m/°C) and 316LN (18 μm/m/°C). Also, the DMWJ made with these consumables have significantly retards carbon migration from low chromium ferritic steel side to high chromium weld metal [1].

A characteristic feature of a DMWJ is metallurgical and material property mismatch resulting from a steep gradient of abruptly changing narrow compositional and microstructural zones with significantly different strength and toughness properties across the weld between two physically different materials [2]. This mismatch states will affect entire failure behavior of DMWJ.

For a reliable structural integrity assessment, one should know the strength and toughness properties of each regions (Base metal (BM), Heat affected zone (HAZ) and Weld metal (WM). So far, many authors [3-5] reported the mechanical property variations in each regions of DMWJ by using miniature tensile specimens but the results reported by them is not accurate because it is case-dependent results. Also, miniature tensile specimens will yield higher elongations compared to standard size specimens. To avoid the above problems, notched cross weld tensile test has been proposed in this investigation. Generally, cross weld tensile test is widely used in industries to qualify welds [6], i.e. whether the failure occurs in the base metal that represents a good scenario, or in the weld metal or HAZ that is often not wanted. Due to the notch, plastic deformation is forced to develop in the notched region and failure occurs due to stress concentration effect.

In this investigation, notch tensile properties of different regions of DMWJ are evaluated by placing the notch at the desired locations. Microhardness survey across the DMWJ is also conducted to identify the weakest region of DMWJ and the characterization of different regions are reported in this paper.

2. EXPERIMENTAL

The base metals used in the investigations are modified 9Cr-1Mo (300×150×25 mm^3) ferritic steel in normalized and tempered condition (1080°C for 1h and 760°C for 1h) and 316LN (300×150×30 mm^3) austenitic stainless steel in solution annealed condition (1150°C for 30min.). The base metals were welded with two different types of filler metals. For the root pass Inconel 82 (ø 1.2 mm) (AWS A5.14, ERNiCr-3) were used. Basically Inconel 82 is a gas tungsten arc welding (GTAW) filler so it recommended for root and second passes. For fill and cap passes Inconel 182 (ø 3.12 mm) (AWS A5.11, ENiCrFe-3) manual metal arc welding (MMAW) electrodes were used. The chemical compositions of base metals and filler metals are shown in Table 1.

The welding was carried out with MMAW process. K-Joint configuration was adopted to fabricate the DMWJ. Before welding, the ferritic steel was buttered with Inconel 182 electrodes. During this process, a pre-heat temperature of 250°C was maintained. After buttering process, the P91 plate was subjected to post-heating

Table 1: Chemical Compositions of Base Metals and Filler Metals (in wt %)

Elements	P91	SS316LN	Inconel 82	Inconel 182
C	0.10	0.02	0.10 max.	0.04
Ni	0.25	12.55	(Ni+Co) 67.01	70.08
Cr	9.06	17.27	18.0-22.0	16.90
Mo	0.79	2.35	---	---
Si	0.18	0.29	0.50 max.	0.69
Mn	0.38	1.69	2.5-3.5	6.20
Cu	0.04	0.04	0.50 max.	0.01
Nb	0.07	0.02	(Nb+Ta) 2.0-3.0	2.09
V	0.20	0.04	---	Ti (0.08)
S	0.01	0.02	0.015 max.	0.01
P	0.01	0.02	0.030 max.	0.007
Fe	Bal.	Bal.	3.0 max.	3.31

Table 2: Welding Parameters used to Fabricate the DMWJ			
Parameters	**Buttering on Modified 9Cr-1Mo side**	**Root pass in GTAW**	**Remaining passes in MMAW**
Current (A)	80	120	70-85
Voltage (V)	22	18	20-23
Speed (mm/min)	150	100	140-160
Heat input (kJ/mm)	0.56	0.76	0.48-0.59
Electrode diameter (mm)	3.15	2	3.15
Preheat temperature (°C)	250	---	---
Inter-pass temperature (°C)	250	---	---
Post heating (°C)	760/2 h	---	---
Shielding gas flow rate (Lit/min)	---	Argon 20L/min	---

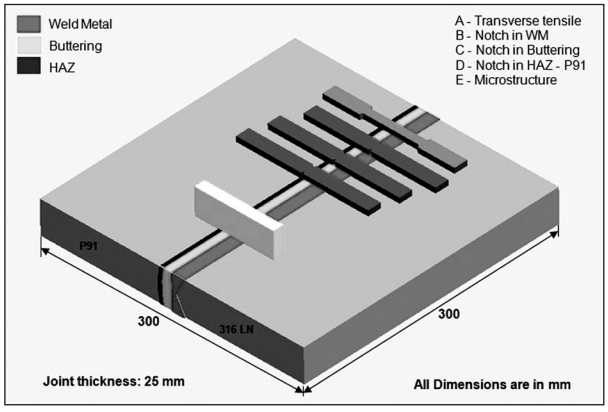
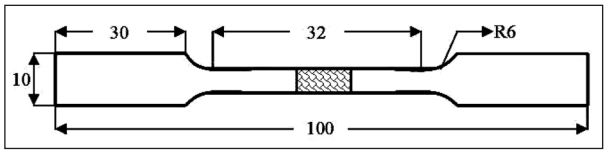
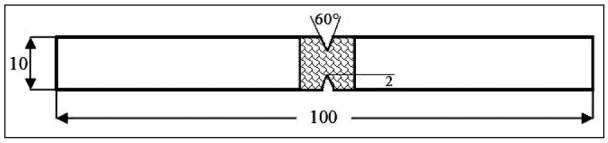


Fig 1. Scheme of Extraction of Tensile Specimens



a. Dimensions of the Tensile Specimen - Unnotch



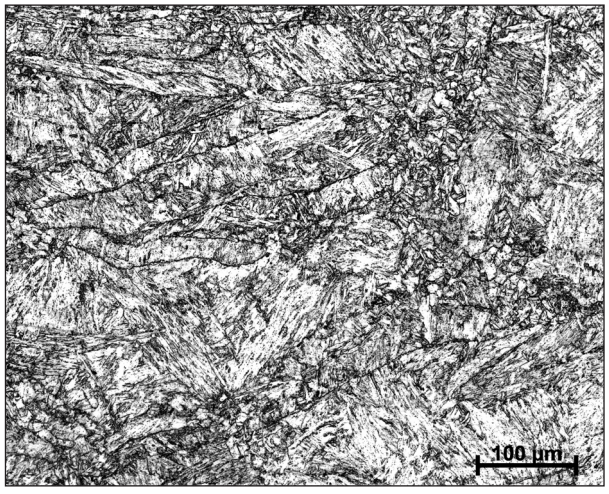
b. Dimensions of the Tensile Specimen - notch

Fig 2 (a-b). Dimensions of the Tensile Specimens

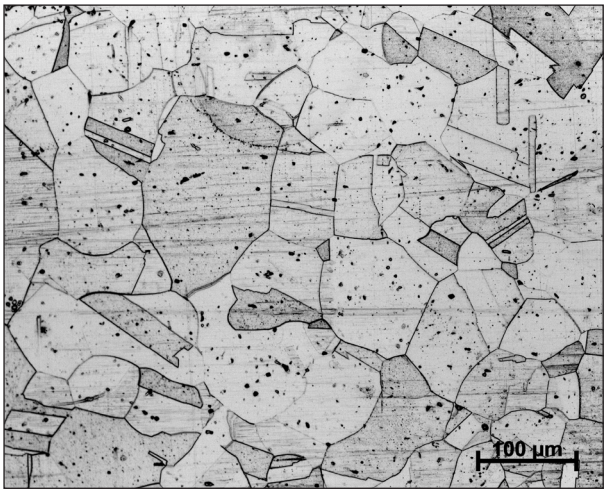
(760°C for 2h) with a heating rate of 150°C/hr followed by furnace cooling. After post heating the buttered P91 plates were subjected to Dye-Penetrant testing (DPT) to identify surface cracks. The welding was carried out between buttered P91 plate and 316LN in 1G (flat-horizontal) position. The welding parameters used to fabricate the DMWJ are shown in Table 2. After welding, the DMWJ was subjected to radiography testing as per ASME Section V (inspection procedure) and the joint was accepted as per ASME Section-III (acceptance criteria).

The tensile specimens were extracted transverse to the welding direction. After extraction, the specimens were sliced through wire-cut electrical discharge machining (EDM) process. The scheme of extraction of specimens is shown in Figure. 1. Room temperature transverse tensile test was performed as per ASTM E8-13 standard. For the notched specimens, the notch was placed in weld metal, buttering, HAZ of ferritic steel side and HAZ of stainless steel side using broach cutter. All the tensile tests were carried out at a constant strain rate of 2.8×10^{-4} s^{-1}. Before testing, the specimens were mirror polished in order to ensure the smoothness. The dimensions of tensile specimens are shown in Figure 2.

Microhardness variations across the DMWJ was carried out using Vicker's microhardness tester. The load and distance between two indentations are 100g and 0.2mm respectively. Microstructural characteristics of DMWJ was carried out by using light optical microscope. Since it is a dissimilar joint, there are three different chemical etchants were used to reveal the microstructural features. For P91 steel villela's reagent was used. For Inconel 82/182, a solution which contains 5g $FeCl_3$, few drops of HCl and 100ml H_2O was used as a etchant. For 316LN, 10 ml HNO_3 , 20 ml HCl and 30 ml of H_2O was used. The fractured surfaces of tensile specimens were analyzed using scanning electron



a. Optical micrograph of P91



b. Optical micrograph of 316LN

Fig 3. Optical Micrographs of Base Metals

microscope. Before testing, the samples were cleaned with acetone in order to remove the contaminants over the fracture surfaces.

3. RESULTS AND DISCUSSION

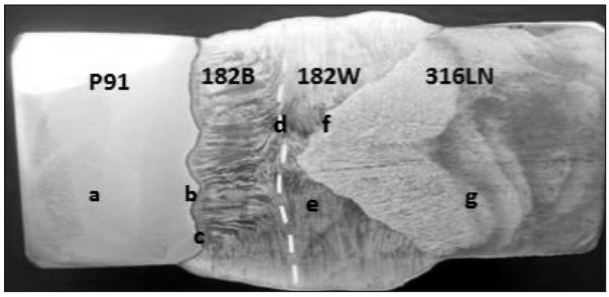
3.1 Macro and Microstructure

The optical micrographs of base metals are shown in Figure 3. The P91 ferritic steel consists of tempered martensite within prior austenite grain boundaries and some of the secondary phase particles were finely distributed in grain boundaries and also within the grains. Jones et al.[7] reported that, these secondary phase particles belong to $M_{23}C_6$ and V_4C_3 type carbides which forms during tempering (760°C for 2h) of the base metal. The optical micrograph of 316LN consists of fully equiaxed austenite grains with a small amount of δ-ferrite in the form of stringers.

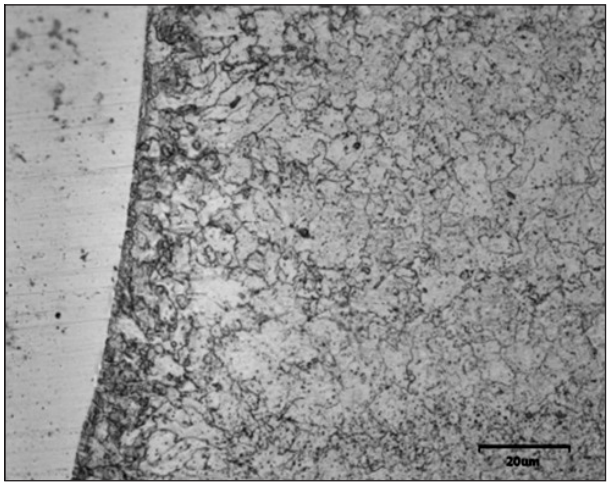
Macrostructure of the DMJ is shown in Figure 4a which is free from macro level defects. The average width of buttering layer is about 6 mm and the grains grown in the transverse direction. A clear interface was observed between P91 and Inconel 182 buttering layer. The micrograph of various regions of DMWJ are shown in Figure 4 (a-f). The optical micrograph of interface region between P91 to 182 buttering is shown in Figure 4b. An evidence of carbon depleted soft zone and carbon enriched hard zone is visible. Formation of these zones are due to the carbon migration from low chromium ferritic steel side to high chromium weld metal. The interface between P91 to 182 buttering shows an additional feature of Type I and Type II boundaries (Figure 4c). Generally, the type I boundary is perpendicular to the fusion boundary whereas, the Type II boundary is parallel to the fusion boundary. Both Type I and Type II boundaries are discontinuous and it is resulted from the change in primary mode solidification (ferritic to austenitic). In Figure 4c, transverse austenite crystal is oriented across the DMWJ and the secondary phase particles are segregated at the grain boundaries. In addition to that, solidification grain boundaries (SGB's) are also visible. Interface between Inconel 182 buttering and 82/182 welding is shown in Figure 4d. From this, a clear transition of transverse to columnar dendrites is visible. This transition occurred mainly because of the different direction of weld cooling which were determined by the different welding procedures for the buttering and weld [8]. The optical micrograph of weld metal is shown in Figure 4e which consists of fully austenite grains oriented towards the direction of weld cooling. The interface between Inconel 82/182 weld metal and SS316LN is shown in Figure 4f. The unmixed zone was observed in the micrograph this may formed due to different melting ranges as well as the element migration between Inconel 82/182 to SS316LN during the welding process.

3.2 Microhardness Survey

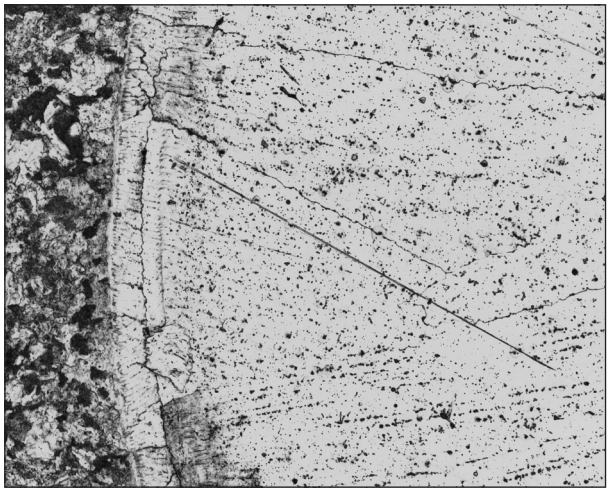
Figure 5 shows the microhardness variation profile across the DMWJ. The hardness measurements were taken at the top, middle and bottom of the joint. A non-uniform hardness profile was recorded along the DMWJ.



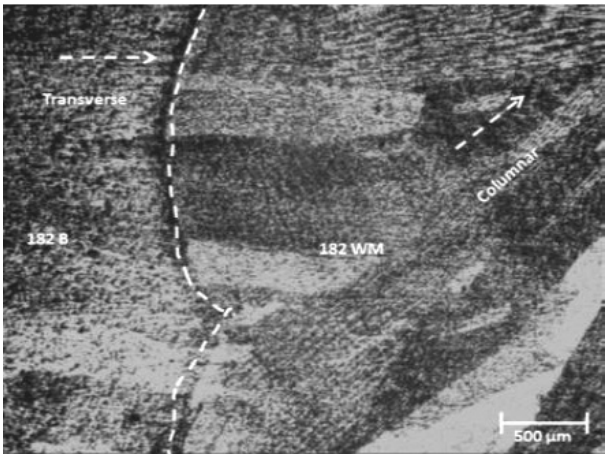
(a) Macrograph of DMJ



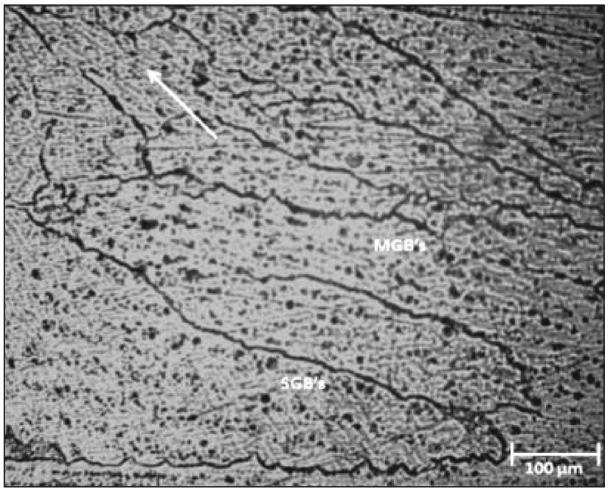
(b) Interface - P91-182B-1



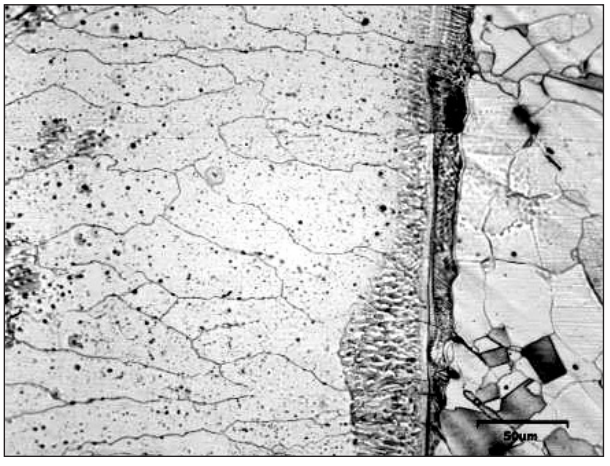
(c) Interface-P91-182B-2



(d) Interface - 182B-82/182W



(e) 182 WM



(f) Interface-82/182W-SS316LN

Fig 4 (a-f). Optical Micrographs of DMWJ

The hardness values of P91 and SS316LN base metals are approximately in a range of 240-260 HV and 210-245 HV, respectively. A sudden dip in the hardness was observed approximately 4 mm from the fusion interface and then it is increased. The hardness at the interface of P91 and 182 buttering was about 260 HV this may be due to the carbon migration from the P91 side to 182 buttering side and the sudden cooling rate during the welding. Both buttering

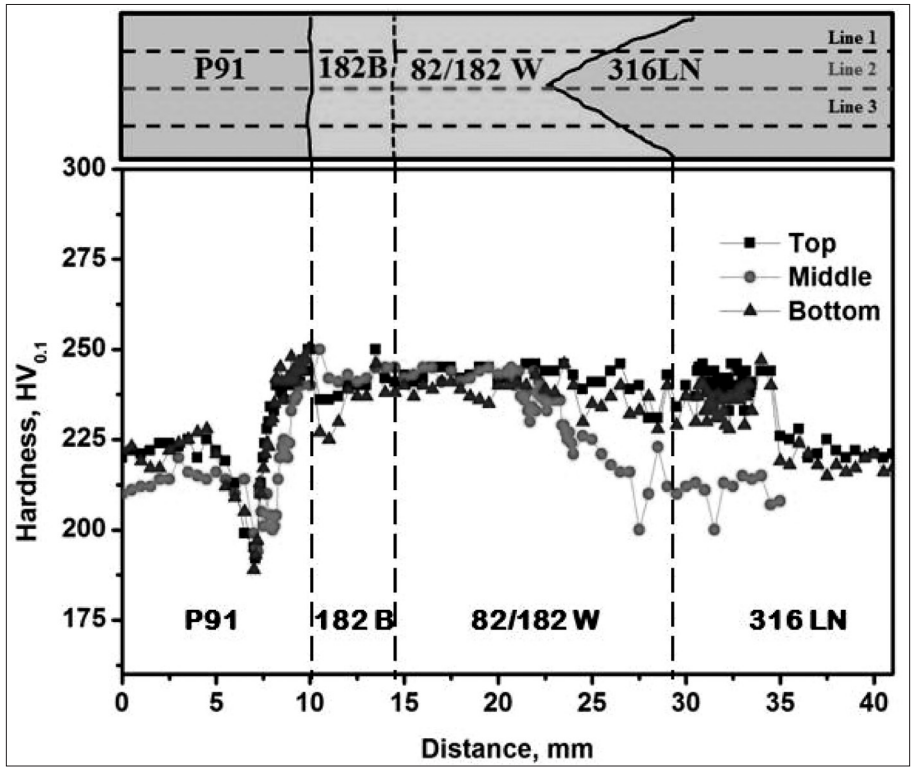
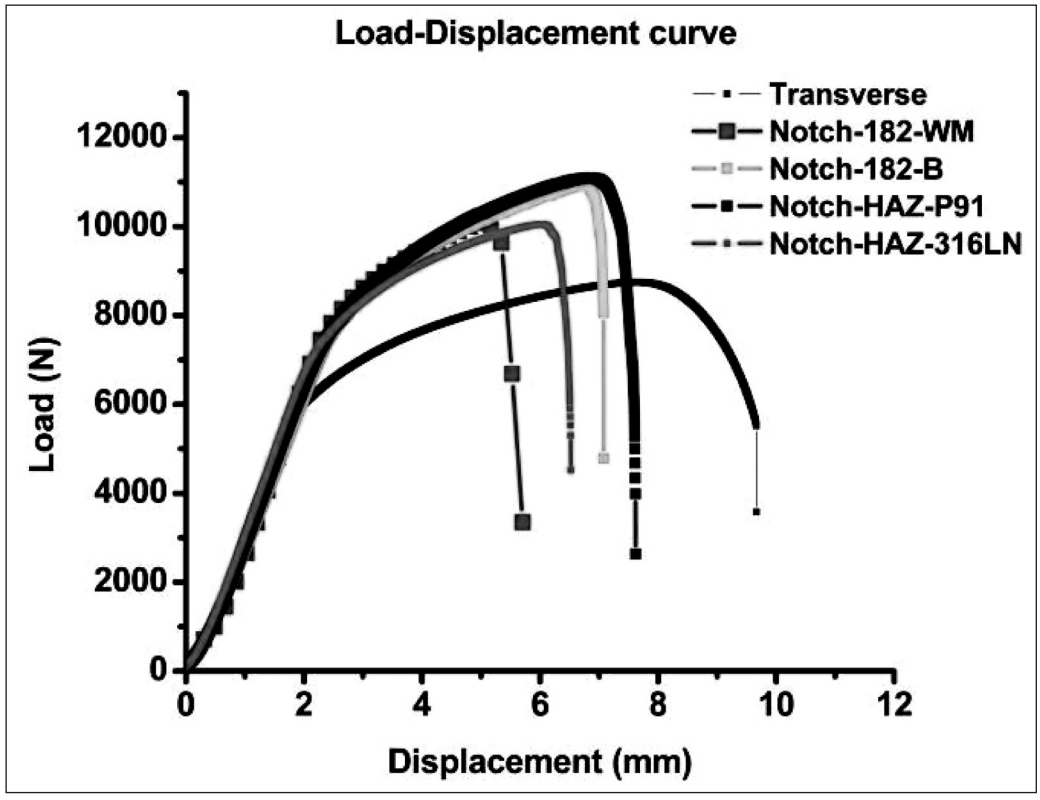


Fig 5. Microhardness Distribution Profile Across the DMWJ

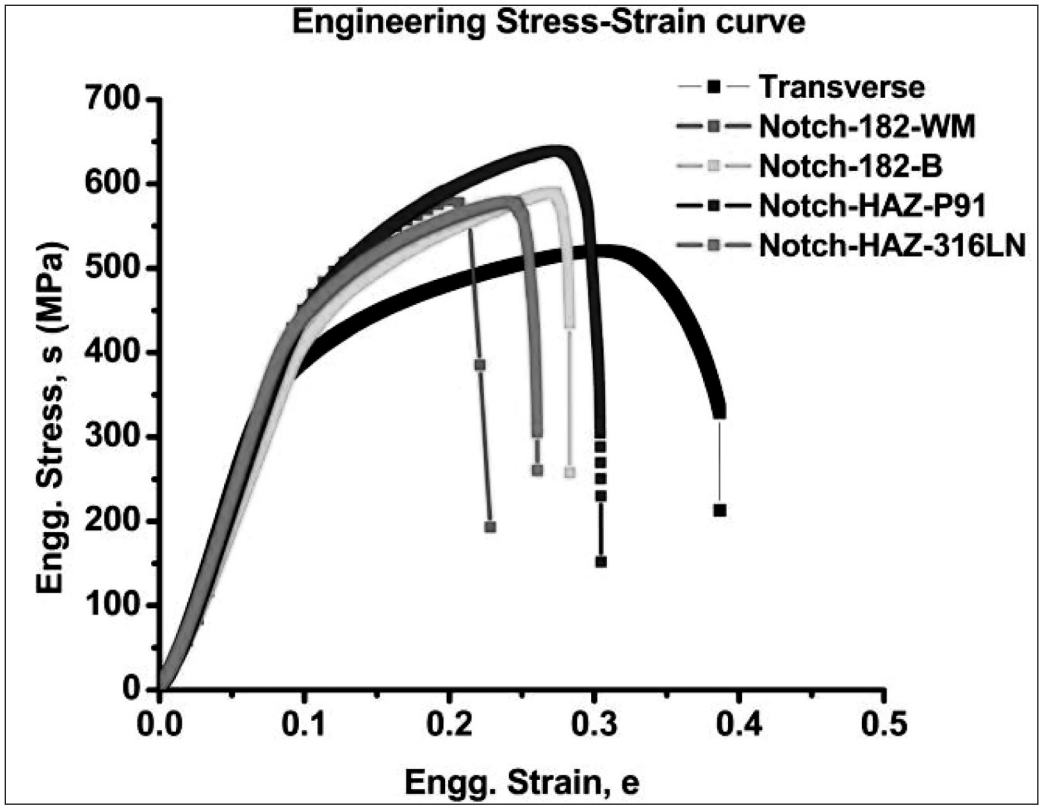
Table 3: Tensile Properties of Base Metals and Different Regions of DMWJ

	0.2 % Yield strength (MPa)	Ultimate tensile strength (MPa)	Elongation in 25mm gauge length (%)	Reduction in cross sectional area (%)	Notch tensile strength (MPa)	Location of failure
P91-BM	590	720	19	55	1090	---
SS316LN-BM	312	590	44	63	707	---
Transverse	394	519	9	82	---	P91 BM
Notch in Weld metal	---	---	---	---	580	---
Notch in Buttering	---	---	---	---	590	---
Notch in HAZ-P91	---	---	---	---	638	---
Notch in HAZ-316LN	---	---	---	---	577	---

and welding are carried out using same filler so there is no appreciable variations in the hardness in these regions. The hardness in the HAZ of SS316LN side is slightly increased compare to its adjacent region. This may be due to the element migration from the weld metal to SS316LN side and repeated tempering results in grain refinement which leads to the increase in hardness [8]. From the hardness survey, it is concluded that the weakest region in the DMWJ is located at 4 mm from the interface of P91 to 182 buttering.



a. Load-displacement curve



b. Engg. stress-strain curve

Fig 6 (a-b). Tensile Curves for Different Regions of DMWJ

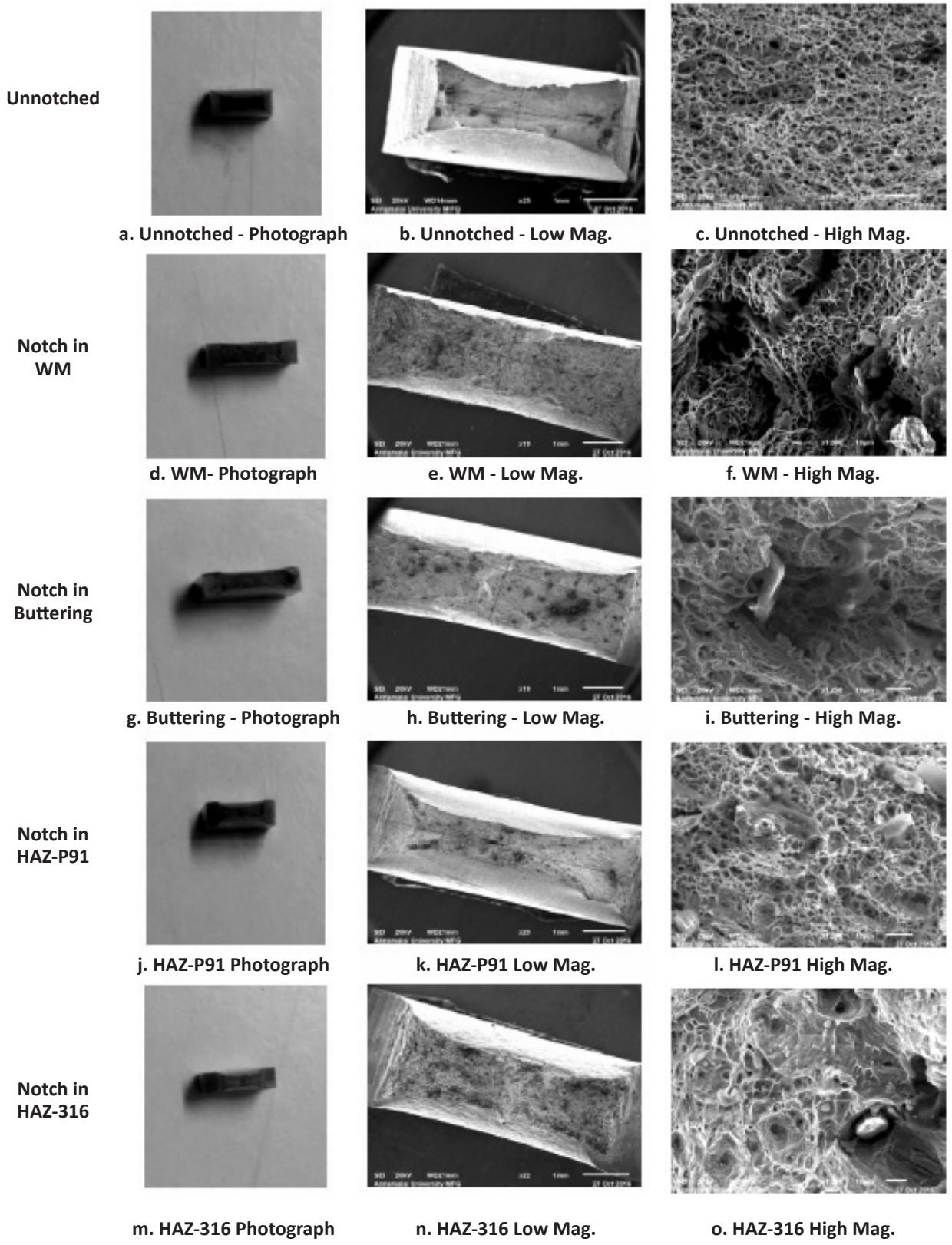


Fig 7 (a-o). SEM-Fractographs of Tensile Specimens

3.3 Tensile Properties

Figure 6 shows the load-displacement and their corresponding engineering stress-strain curves for various regions of DMWJ. In each case three specimens were tested and the average values are reported in Table 3.

The tensile properties of base metals are also included for comparison. From the results, it is understood that, the transverse tensile specimens were failed in the P91 side which is approximately 4.5 mm from the P91 to Inconel 182 buttering interface. These results are in good agreement with the hardness profiles of DMJ. The transverse tensile specimens were failed at the lowest hardness distributed region. Among the different regions of DMJ, the HAZ of P91 side specimens showed highest notch tensile strength compared to other regions and this may be because of carbon enriched hard zone formed adjacent to the interface of P91. Notch tensile strength for buttering region is higher compared to weld metal. Even though it is having a similar chemical composition, the base metal dilution is high for buttering region and the grains were oriented along the loading direction. So the strength is moderately higher compared to weld metal. The lowest notch tensile strength is observed for HAZ of 316LN. From the tensile test results, it is understood that the strength mainly depended upon the local microstructural features developed during welding and the grain orientation.

3.4 SEM Fractographs

The fracture surfaces of tensile specimens are shown in Figure 7. Low and high magnification images are included for each regions of DMWJ.

Low magnification fracture surface of smooth specimen is shown in Figure 7b. The width and thickness of the specimens before testing was about 6 mm and 3 mm . After testing, the width and the thickness of the specimens reduced to 3.4 mm and 0.8 mm respectively, this shows a significant amount of plastic deformation is observed before failure. High magnification fracture surface (Figure 7c) consists of fine equiaxed dimples with small amount of tear ridges. The fracture pattern is very similar to that of base metal, because it fails at the interface between HAZ to BM.

Fractographs of Inconel 182 buttering and Inconel 82/182 weld metal is shown in Figure 7 (d-i) in which the fracture is dominated by ductile dimples and teat ridges and some the secondary phase particles are also visible, in both the fracture surfaces some deep cavities are presented. The volume fraction of ductile dimples in Inconel 82/182 weld metal is more compared to Inconel 182 buttering. In figure 7(d-f), the fracture surface consists of shallow dimples and some flat facets. Fractographs of HAZ of 316LN side is shown in Figure 7 (m-o) which consists of large and deep dimples surrounded by tear ridges and the secondary phase particles are also visible which acts as a crack initiator during tensile testing.

4. CONCLUSIONS

The dissimilar joint between P91 grade ferritic steel and 316LN stainless steel was successfully fabricated without any macro and micro level defects. From this investigations, the following conclusions are derived.

1. The microstructure across the DMWJ is heterogeneous in nature. The interface microstructure between P91 to 182 buttering reveals carbon depleted soft zone and carbon enriched hard zone due to carbon migration from low chromium ferritic steel side to high chromium weld metal. The interface between 182 welding to 316LN shows a thin layer of unmixed zone.
2. A non uniform hardness profile was recorded across the dissimilar joint. Highest hardness is observed at the interface between P91 to 182 buttering side. This may be due to the carbon migration from P91 to 182 buttering. The hardness is low at the outer edge of the HAZ of P91 because of partial transformation of grains.
3. All transverse tensile specimens were failed at the outer edge of the HAZ of P91 side. The average tensile strength of transverse specimens is found to be lower than the base metals. Among the different regions of DMWJ, the HAZ of P91 steel yielded highest notch tensile strength.

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✪ **25 - 28 Aug 2017**
International fair of the manufacturing industry
Diamond Island Convention and Exhibition Center, Diamond Island opposite the Hun Sen Park, Phnom Penh, Phnom Penh, Cambodia
Contact:
Chan Chao International Co., Ltd., 3F, No.185, Kangchien Road, 10041 Taipei, Taiwan
Tel: +886 (2) 26596000 Fax: +886 (2) 26597000
Email: sales@chanchao.com.tw
Web: www.chanchao.com.tw

✪ **03 - 06 Sep 2017**
International trade fair for machinery, machine parts and tools
Erbil International Fair Ground,
Sami Abdel Rahman Park, Erbil, Arbil, Iraq
Contact:
Pyramids Grup Fuarcilik A.S., Kucukbakkalkoy Mah. Kocasinan Cad.Gumrukcu Sok.No.8, 34750 Istanbul, Turkey
Email: info@pyramidsfair.com
Web: www.pyramidsfair.com

✪ **12 - 14 Sep 2017**
Metalworking and Manufacturing Exposition and Conference
Los Angeles Convention Center, 1201 S Figueroa St, 90015 Los Angeles, California, USA
Contact:
Society of Manufacturing Engineers SME
One SME Drive, MI 48121 Dearborn, USA
Tel: +1 (3)13 4253000 Fax: +1 (3)13 4253400
Email: events@sme.org
Web: www.sme.org

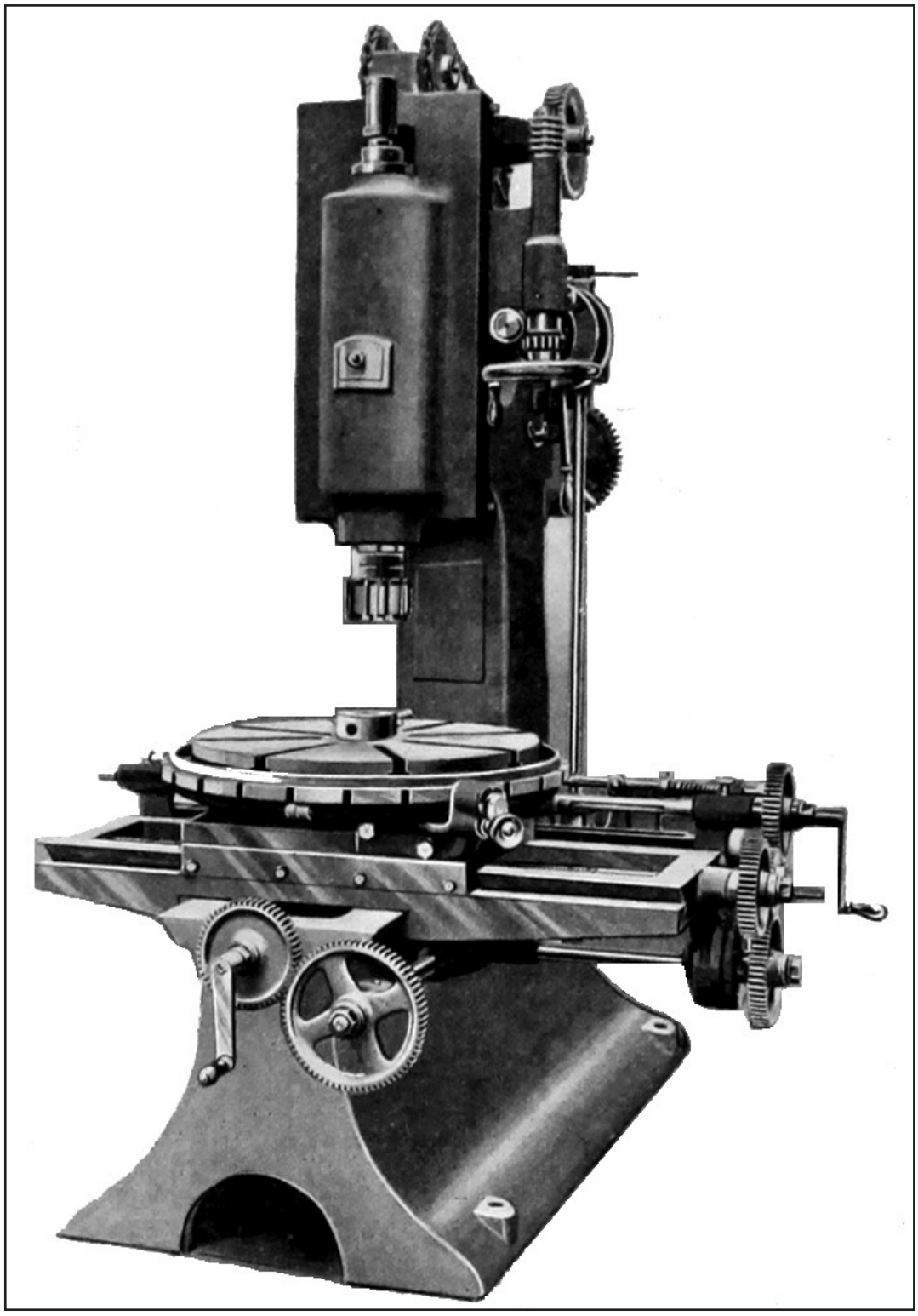
✪ **12 - 15 Sep 2017**
Trade fair for metal-mechanical industries
Megacentro Expoville, Rua 15 de Novembro, 4.305, 89216-202 Joinville, Santa Catarina, Brazil
Contact:
Messe Brasil, Rua Araranguá, 77 - Térreo
89204-310 Joinville, Brazil
Tel: +55 (0)47 34513000
Fax: +55 (0)47 34513001
Email: intermach@messebrasil.com.br
Web: www.tradefairdates.com

✪ **18 - 20 Sep 2017**
Trade fair for heat treatment
Expocentre Fairgrounds, Krasnopresenskaya nab., 14, 123100 Moscow, Moscow, Russian Federation
Contact:
Mir-Expo, Yury Andropov`s avenue, 22
115533 Moscow, Russian Federation
Tel: +7 (4)99 6180565 Fax: +7 (4)99 6183688
Email: info@mirexpo.ru Web: www.mirexpo.ru

✪ **18 - 23 Sep 2017**
World trade fair for machine tools and metalworking
Messe Hannover, Messegelände, 30521 Hanover, Lower Saxony, Germany
Contact:
VDW e.V., Corneliusstr. 4, 60325 Frankfurt, Germany, Tel: +49 (0)69 7560810
Fax: +49 (0)69 75608111
Email: vdw@vdw.de
Web: www.vdw.de

✪ **19 - 21 Sep 2017**
Trade fair for automotive test, evaluation and quality engineering
Shanghai Everbright Convention & Exhibition Center, 5F, B Block, 66 Caobao Road, Xuhui district, 200235 Shanghai, Shanghai, China
Contact:
UKIP Media & Events Ltd., Abinger House Church Street, RH41DF Dorking, United Kingdom of Great Britain and Northern Ireland
Tel: +44 (0)1306 743744
Fax: +44 (0)1306 742525
Email: info@ukipme.com
Web: www.ukipme.com ◘

Vintage Machine Tool: Vertical Milling Machine, (Darling & Sellers) 1902



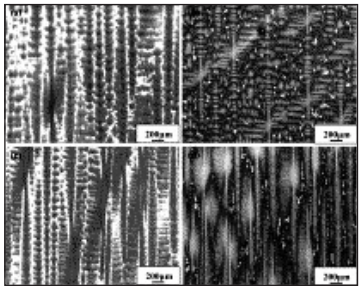
Courtesy google images

MANUFACTURING TECHNOLOGY ABSTRACTS

MANUFACTURING TECHNOLOGY ABSTRACTS

CASTING & FOUNDRY PRACTICE

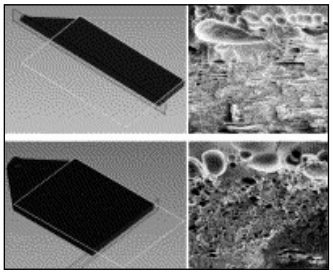
111202 High thermal gradient directional solidification method for growing superalloy single crystals



Wang, F; Ma, DX; Zhang, J; Bogner, S; Bührig-Polaczek, A ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 3112, Pages 10]*** The experiments here were conducted at withdrawal rates of 3 mm/min and 1 mm/min using a CMSX-6 and a CMSX-4 superalloy, respectively. The process was assessed in terms of the thermal gradient (GL), structural refinement, microsegregation and porosity distribution, and compared to those using a Bridgman process. The GL of the process was 200–236 K/cm, which was 10–12 times higher than that in the Bridgman process. A more refined microstructure was produced having average primary and secondary dendrite arm spacing values as low as 243 μm and 72 μm, as well as 272 μm and 76 μm in the CMSX-6 and the CMSX-4 castings, respectively. The diameter of γ′ phase in the dendrite core of CMSX-6 and CMSX-4 castings was reduced from 0.8 μm to 0.3 μm and from 1.2 μm to 0.6 μm, respectively. The average areas of (γ′ + γ) eutectic pools became smaller and more homogeneously distributed. The mean pore sizes in the castings were reduced by 57% and 43% for the CMSX-6 and CMSX-4 superalloys, respectively, and the area fractions of the pores in the CMSX-6 and CMSX-4 samples were 16% and 12% of those produced in the Bridgman samples. The segregation coefficients of the major alloying elements were closer to unity than those in the Bridgman process, which indicates that the composition distribution is more uniform.

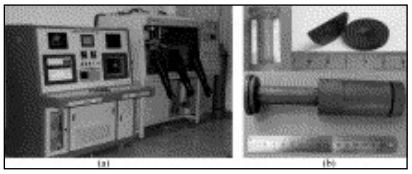
111203 Foam injection molding of poly (Lactic Acid) with environmentally friendly physical blowing agents

Pantani, R; Volpe, V; Titomanlio, G ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 3098, Pages 10]*** Biodegradable



polymers present a very narrow processing window, with the suitable processing temperatures close to the degradation conditions. The aim of this work was to analyze the foamability of a biodegradable polymer, namely the poly(lactic acid), PLA. Foam injection molding was conducted by using a blowing agent under high pressure and temperature to produce parts having a cellular core and a compact solid skin (the so-called “structural foam”). The effect of a physical blowing agent (PBA) on density and morphology of foamed parts was characterized. A masterbatch of PLA and talc was prepared and adopted to obtain a compound containing 3% of talc. On adding this percentage of talc to PLA it was possible to obtain foamed parts with a much better morphology.

111204 Effect of process parameters on copper droplet ejecting by pneumatic drop-on-demand technology



Zhong, Song-yi; Qi, Le-hua; Luo, Jun; Zuo, Han-song; Hou, Xiang-hui; Li, He-jun ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 3089, Pages 9]*** Stable generation of copper droplets is a key issue in fabricating copper parts by drop-on-demand (DOD) technology. The process parameters such as supply pressure and electronic pulse width have significant effect on pressure variation and droplet formation. In the present work, a pressure acquisition system was first set up to measure the pressure variation in crucible. Then the measured pressure data were applied on a 2D axisymmetric model as inlet conditions to study the influence of process parameters on copper droplet formation. The results indicated that the peak pressure in crucible increased linearly with the increase of supply pressure. As supply pressure increased, the jet velocity and the limiting length increased to critical value and droplet could be generated. The peak width increased with the rise of

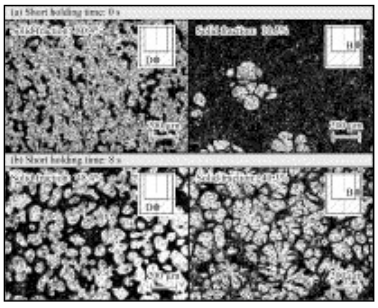
electronic pulse width. By increasing the electronic pulse width, the time of pressure above threshold value increased and the jet limiting length grew to critical value for breakup. However, if supply pressure and electronic pulse width were too large, satellite droplets would be formed. Pure copper droplet generating experiments were conducted to obtain appropriate parameters. Single droplet was generated while supply pressure was between 60 kPa and 100 kPa and pulse width was between 550 µs and 1550 µs. Also the range of pulse width varied as the supply pressure increased for generating single droplet. The statistics of droplet diameter suggested that droplet diameter increased with the increase of supply pressure. Electronic pulse width had influence on the droplets size and the standard deviation increased with the increase of electronic pulse width. So small supply pressure and electronic pulse width should be used for generating uniform droplets.

111205 Improving the biocompatibility of non-removable dentures by using egg shell waste: an explicit framework

Rupinder Singh; Sunpreet Singh ***[A I M T D R Conference Proc, 12 2016, Starting Page 30, Pages 4]*** Non-removable partial/complete dentures (NRPD/NRCD) are gaining wide acceptance in these days due to the elimination of gum resorption when compared with removable dentures. This paper highlights an explicit framework for the development of NRPD/NRCD (with improved biocompatibility) through fused deposition modelling assisted investment casting (FDMAIC) by using an alternative filament reinforced with hydroxyapatite (HAp) particles. From the preliminary geometrical measurements, it has been found that the dimensions of the casted denture are lying within acceptable range. However further testing (such as: in-vitro behaviour of casted denture and its metallurgical analysis) is mandatory to strengthen the claims, which is the part of upcoming research activities.

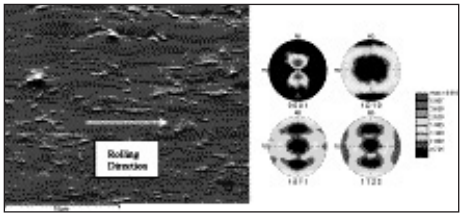
FORMING

111206 Effects of forming conditions on homogeneity of microstructure and mechanical properties of A6061 aluminum alloy manufactured by time-dependent rheoforging on a mechanical servo press



Meng, Yi; Sugiyama, Sumio; Tan, Jianbo; Yanagimoto, Jun ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 3037, Pages 11]*** The different forming behaviors of the solid and liquid phases in semisolid metal slurry during deformation result in products with inhomogeneous quality. A mechanical servo press with the capability of multistage compression was employed to forge A6061 aluminum alloy in the semisolid state. A time-dependent rheoforging strategy including mechanical stirring, a fast first compression, short holding, and a secondary compression was designed to improve the homogeneity of rheoforged samples. The distributions of the microstructure and mechanical properties, such as the solid fraction, hardness, and deformation resistance, of samples manufactured under various experimental conditions were investigated. When the stirred semisolid A6061 slurry was forged in the temperature range from 625 to 628 °C with a short holding time of 4 s and the upper die preheated to 300 °C, samples with a homogeneous microstructure and mechanical properties were manufactured. The homogeneity of rheoforged samples was attributed to the controllable free motion capability of the mechanical servo press and the adjustable fluidity and viscosity of the semisolid slurry.

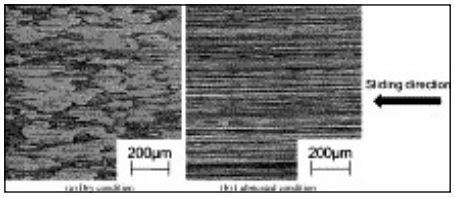
111207 Anisotropic mechanical behavior and formability criterion for zinc sheets



Milesi, Marc; Logé, Roland E; Jansen, Yann ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 2869, Pages 8]*** The mechanical behavior of zinc has been studied and linked to the formability of sheets. An anisotropic elastic–viscoplastic behavior law has been developed to take into account the anisotropy of the material. Anisotropy is induced

by crystallographic and morphological textures, and possibly by the spatial distribution of intermetallics. The temperature dependence is introduced through a Zener–Hollomon type term. The resulting anisotropic formability of sheets implies a new approach by adapting the forming limit diagram with a stress based criterion. This approach is confronted and validated by considering the industrial forming of a head clip.

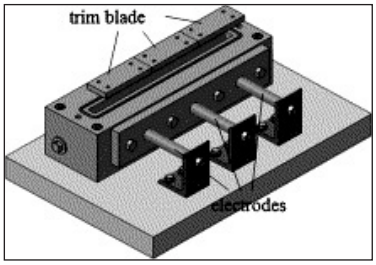
111208 Thermal behavior of aluminum-coated 22MnB5 in hot stamping under dry and lubricated conditions



Azushima, Akira; Uda, Kosuke; Matsuda, Hiroki ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 3031, Pages 6]*** The hot stamping of aluminum-coated 22MnB5 has usually been conducted under dry condition, for which the forming load is high since the coefficient of friction is over 0.5. In order to decrease the forming load, the authors previously proposed the use of a lubricant to decrease so that the coefficient of friction from over 0.5 to 0.3. However, it is necessary to understand the heat transfer property in hot stamping under lubricated condition. The purpose of this paper is to examine the heat transfer property of aluminum-coated 22MnB5 in hot stamping under dry and lubricated conditions. In this study, the die and specimen temperatures were measured during compression and compression-sliding tests under dry and lubricated conditions using the hot flat drawing test simulator. In the compression test, the die and specimen temperatures measured under dry and lubricated conditions were the same. On the other hand, in the compression-sliding test up to a sliding distance of 70 mm, the die temperature under lubricated condition was lower than that under dry condition, and it was found that the heat transfer under lubricated condition is superior to that under dry condition. Consequently, there is a difference between the specimen temperatures under dry and lubricated conditions. However, from the results of the tensile test, there is no difference between the tensile strengths under dry and lubricated conditions.

SHEERING FORMING

111209 Analysis of loads on the shearing edge during electrohydraulic trimming of AHSS steel in comparison with conventional trimming

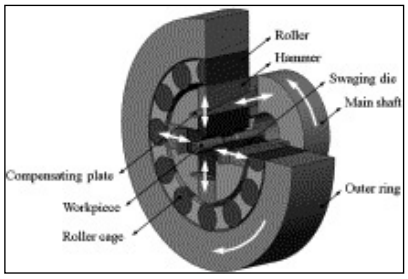


Tang, Zejun; Golovashchenko, Sergey F; Bonnen, John F; Mamutov, Alexander V; Gillard, Alan J; Bonnen, David ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 2843, Pages 15]*** In order to achieve further weight reduction in automotive components, the technology of manufacturing of automotive panels from advanced high strength steels is being developed. Electrohydraulic trimming technology eliminates the necessity of accurate alignment of the shearing edges in trimming operation. Analysis of loads on the tool during high-rate EH trimming process has been performed. In order to investigate the effect of the process on the shearing edge performance, a dedicated finite element analysis procedure combining 3D shell and 2D solid models was developed. EH trimming experiments were carried out to validate the simulation model where elastic plastic deformation of the shearing edge was taken into account. The effects of the die geometry and number of trimming cycles on the tool contact loads and tool's plastic deformation were analyzed. This analysis was based on numerical simulation of deformation and fracture of the blank being trimmed in contact with the deformable shearing edge. Numerical analysis of the shearing edge deformation was performed in elasto-plastic formulation for the D2 tool steel inserts used in the experimental study and also in elastic formulation to define the maximum stresses which tool material needs to withstand to avoid its plastic deformation. The results of the analytical study indicate that the maximum contact pressure is applied to the trimming tool at the lower endpoint of the shearing edge, but the point of maximum plastic deformation in the tool is found on the vertical wall of the shearing edge where it contacts the area of the blank where separation takes place. The shearing edge of the EH trimming die experiences less contact pressure and less plastic deformation with increase of the radius of the shearing edge. The shearing edge of the EH trim die has a tendency to dull after a number of trimming cycles. In addition, when compared with conventional trim die, the shearing edge of the EH trimming tool experiences slightly higher (10–15%) contact loads than in conventional trimming. However, plastic

deformations occurring in the conventional trim die for shearing of identical material are larger. Analysis of loads on the EH trimming tool was repeated for purely elastic tool material to formulate the requirements to the material of the shearing edge.

SHEET METAL WORKING

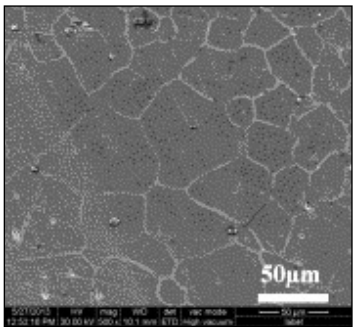
111210 Recess swaging method for manufacturing the internal helical splines



Zhang, Qi; Mu, Dong; Jin, Kaiqiang; Liu, Yong ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 2971, Pages 14]*** With the advantages of minimized stress concentration and allowing a combination of rotation and axial motion, internal helical splines have been widely used in automotive and aeronautic industries. However, this type of splines can only be manufactured using machining or extrusion method. This paper studied the recess swaging method, a net-shape forming process, for manufacturing the internal helical splines. In order to investigate the deformation tendency of workpiece along the thickness direction, Finite Element (FE) simulations and experiments were firstly performed on the recess swaging of tube without mandrel. Results show that the stress state in the forging zone is triaxial compressive except for the tensile axial stress at the inner surface of the tube. Moreover, during the recess swaging process material mainly flows along the axial and thickness direction, but the axial flow dominates. With increasing the reduction in outer radius and the wall thickness, metal flow along the axial direction increases but along the thickness direction decreases. Furthermore, based on the fundamental research on recess swaging experiments and FE simulations on the recess swaging method for manufacturing the internal helical splines were conducted. After the recess swaging, the hardness at the bottom of the tooth improved approximately 56.9%, while that at other zones increased 41%. The strength and the wear resistance of tooth were also improved. In summary, the recess swaging process provides an effective method for manufacturing the internal helical splines.

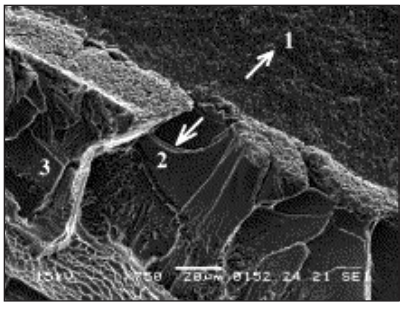
JOINING & ASSEMBLY

111211 Microstructural characterization of liquid nitrogen cooled Alloy 718 fusion zone



Manikandan, SGK; Sivakumar, D; Prasad Rao, K; Kamaraj, M ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 3141, Pages 9]*** The interdendritic Laves phase and the microsegregation have been investigated in Alloy 718 fusion zone cooled with liquid nitrogen during welding. Conventional GTA welding process was employed with modified waveform and two types of shielding gas and filler metal (solid solution and age hardenable). The weld cooling rate was enhanced using liquid nitrogen cooling during Gas Tungsten Arc welding process. The resultant fusion zone microstructures were characterized using the metallurgical tools. Dendrite remelting phenomenon was observed from the optical micrographs. It was found that the enhanced cooling rate with liquid nitrogen reduced the interdendritic phases which were confirmed in both the electron microscopic and the X-ray diffraction analysis. The elemental mapping in scanning electron microscope-energy dispersive spectral analysis also confirmed the reduced microsegregation. The dendrite arm spacing was reduced from the range of 15–54 µm (CCPHE–CCAR, conventional) to 3–17 µm (CCPHE–CCAR, liquid nitrogen cooled) for the employed process variables. The computed weld cooling rate was found to be enhanced from seven to fifteen times than the conventional welding process.

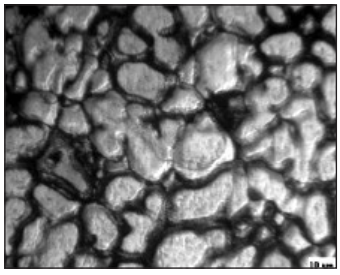
111212 Steel to titanium solid state joining displaying superior mechanical properties



Miriyev, Aslan; Barlam, David; Shneck, Roni; Stern, Adin; Frage, Nachum ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 2884, Pages 7]*** Joint configuration with Ti inserts, which allows the increase of the

bonded area of similar materials at the expense of that of dissimilar ones, is suggested. The force to failure for the specimens with the suggested configuration was about two fold higher than that for the specimens with the planar interface. Microstructural analysis of the joints, fracture characterization, mechanical testing and finite elements simulation were conducted in order to elucidate the mechanical behavior of the suggested joint configuration. Failure of joints with Ti-inserts is governed by the brittle behavior of TiC and α-Ti layers, located at the steel–Ti interface, with cracks initiation within the interfacial layer. The cracks propagate first into the brittle α-Ti phase and then cause the fracture in the Ti/Ti bond. The results of finite elements analysis are in good agreement with the analysis of the fracture surfaces.

111213 SiC and Al2O3 Reinforced friction stir welded joint of aluminium alloy 6061



Aleem Pasha; Ravinder Reddy, P; Laxminarayana, P; Khan, Ishtiaq Ahmad ***[AIMTDR Conference Proc, Dec 2016, Starting Page 48, Pages 4]*** In this paper the Mechanical and Metallurgical behavior of un-reinforced, SiC reinforced and Al2O3 reinforced friction stir welded butt joints of AA6061 aluminium alloy has been investigated. 10%, 15%, 25%, 30% volume fraction of Silicon carbide (SiC) and Aluminium Oxide (Al2O3) particulates were added at weld interface while welding to enhance the mechanical properties at weld zone. This work has been focused to study the effect of SiC and Al2O3 as reinforcing material along with different volume proportions on the mechanical properties of friction stir welded joint of AA6061. The experimental results indicated that the reinforcing material and percentage of reinforcing material has a major effect on the mechanical properties of friction stir welded joint. The results of reinforced friction stir welded joints were compared with mechanical properties of parent material and without reinforced friction stir welded joint. Comparison studies have been included between the results of SiC and Al2O3 reinforced friction stir welded joints. The best results have been obtained at 25% and 30% volume fraction reinforced particulates of Silicon Carbide and Aluminium Oxide respectively. Mechanical properties were enhanced more with SiC than Al2O3 as reinforcement Microstructures were captured at nugget and heat affected zones and compared with the microstructure of parent material.

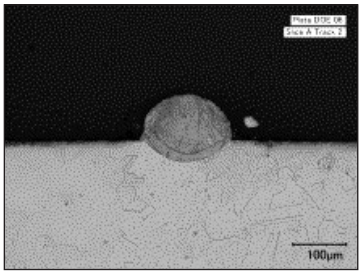
MACHINE ELEMENTS & MECHANISMS

111214 High ratio power dense planetary drive for rotorcraft applications

Xiaolan Ai, Curtis Orkin and Randy Kruse ***[J of Mechanical Design, v 136, n 2, Feb 2014, Starting Page 021010, Pages 10]*** Epicyclic geartrains are known to provide high power density and have become the geartrain of choice for the main power flow in virtually all rotorcraft designs. This paper presents a unique compound planetary design targeting a helicopter main gearbox transmission application. The design significantly improves power density over conventional geartrains through its innovative planet gear load-sharing configuration along with the utilization of high-performance materials for gears and bearings. Design studies were conducted comparing the power density of this new design to a baseline gearbox design. The results of these studies demonstrate an estimated 38% power density improvement over the baseline configuration. Of the total improvement, 86% is attributed to the novel load-sharing configuration while 14% is attributed to utilization of advanced materials and processes.

MACHINING

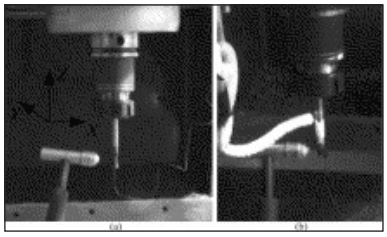
111215 Observation of keyhole-mode laser melting in laser powder-bed fusion additive manufacturing



King, Wayne E; Barth, Holly D; Castillo, Victor M; Gallegos, Gilbert F; Gibbs, John W; Hahn, Douglas E; Kamath, Chandrika; Rubenchik, Alexander M ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 2915, Pages 11]*** Laser powder-bed fusion additive manufacturing of

metals employs high-power focused laser beams. Typically, the depth of the molten pool is controlled by conduction of heat in the underlying solid material. But, under certain conditions, the mechanism of melting can change from conduction to so-called "keyhole-mode" laser melting. In this mode, the depth of the molten pool is controlled by evaporation of the metal. Keyhole-mode laser melting results in melt pool depths that can be much deeper than observed in conduction mode. In addition, the collapse of the vapor cavity that is formed by the evaporation of the metal can result in a trail of voids in the wake of the laser beam. In this paper, the experimental observation of keyhole-mode laser melting in a laser powder-bed fusion additive manufacturing setting for 316L stainless steel is presented. The conditions required to transition from conduction controlled melting to keyhole-mode melting are identified.

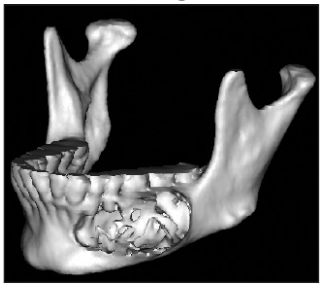
111216 The influence of cryogenic cooling on milling stability



Huang, Xinda; Zhang, Xiaoming; Mou, Haikuo; Zhang, Xiaojian; Ding, Han ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 3169, Pages 10]*** Cryogenic cooling is emerging as an effective process for high performance machining. However, the influence of cryogenic cooling on milling stability is seldom reported. This paper involves experimental study on the effect of cryogenic cooling on milling stability, using a dedicated cryogenic cooling system to applying liquid nitrogen (LN2) jet to the cutting zone. We observe that cryogenic cooling leads to higher stability limit compared with conventional milling operations, which indicates that the cutting efficiency can be improved greatly in LN2 environment as opposed to the conventional one. The stability improvement is explained from the perspective of machining dynamics parameters variation between the two conditions. Cutting force coefficients and modal parameters of spindle-tool system are identified during cryogenic machining, then milling stability lobe diagrams are predicted by time domain and frequency domain methods. On the basis of milling stability analysis, the enhancement of stability boundary is attributed to the significant reduction of cutting force coefficients during cryogenic cooling. Additionally, the experiment result indicates that cryogenic cooling decreases the dominant modal frequency of the spindle-tool system, which shifts the milling stability boundary slightly to lower spindle speed range. The explanations are verified by a plenty of cutting tests.

NON TRADITIONAL MACHINING

111217 Reconstruction of cancer defected mandible using additive manufacturing



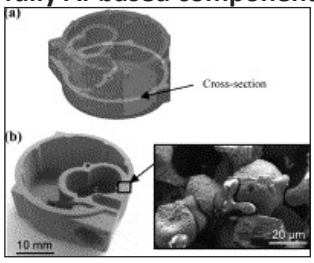
Manmadhachary, A; Ravi Kumar, Y; Krishnanand, L ***[AIMTDR Conference Proc, Dec 2016, Starting Page 34, Pages 5]*** Additive Manufacturing (AM) is the emerging technology in medical science. In this technology data is provided through Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) etc. Design and Fabrication of cancer defected mandible prosthesis need to have certain characteristics such as biological, mechanical and anatomical necessities. The titanium alloy is used to manufacture prosthesis because of its biocompatible and non-corrosive in nature. The density of titanium material is greater than the density of bone, so the weight of the prosthesis is needed to be optimized. The prosthesis model is optimized from various elements (Rectangle, Square, Hexagonal and Auxetic) to get optimal porosity. Response Surface Methodology (RSM) is used to find out optimal strength and weight. The optimum design for mandible defected prosthesis is fabricated based up on simulation results. The optimal deigned prosthesis has the equal bone strength to replace the defected bone portion. The mandible and prosthesis models were fabricated by Fused Deposition Modelling (FDM) technique. Theses fabricated medical models were used for surgical procedures..

111218 Parametric appraisal of tensile strength of FDM build parts

Mishra, Swayam Bikash; Mahapatra, Siba Sankar ***[AIMTDR Conference Proc, Dec 2016, Starting Page 39, Pages 4]*** Manufacturing industries are contemplating to develop new technologies for production of complex end use parts possessing high strength and low product development cycle in order to meet the global competition. Fused deposition modelling (FDM) is one of the proficient technologies having the ability to build accurately

3D complex geometry parts, with reasonably less time and material waste. Due to the build mechanism (layer-by-layer), the tensile strength of FDM build part is largely influenced by the selection of FDM process parameters. Therefore, using a design of experiment approach (DOE), effect of six controllable process parameters such as layer thickness, part orientation, air gap, raster width, contour number and raster angle on the tensile strength of the FDM build is experimentally studied. Using surface plots and scanning electron microscopy (SEM) images, influence of process parameters and failure criteria are analysed and discussed. One empirical model is developed relating process parameters with the tensile strength of the FDM build parts. Finally, a model based on least square support vector machine (LSSVM) technique is proposed to predict the tensile strength of FDM build parts.

111219 Additive manufacturing of lightweight, fully Al-based components using quasicrystals



Kenzari, Samuel; Bonina, David; Dubois, Jean-Marie; Fournée, Vincent ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 3108, Pages 4]*** This article addresses a still-open question in additive manufacturing of lightweight metallic components. We find that using Al-based quasicrystalline particles allows extending the selective laser sintering technology to produce Al-based parts of any complex shape. The process consists in selectively melting a powder blend containing a binder and quasicrystalline particles to construct a three-dimensional pre-form. In a second step, the pre-form is infiltrated by a conventional aluminium alloy in a furnace through a thermal cycle under an inert atmosphere. The aluminium alloy reacts with the quasicrystalline particles, inducing phase transformations and ending with a manufactured product of good mechanical properties that is harmless to the environment and cost-effective.

111220 Parametric optimization of 3D printing process using MCDM method

Vinodh, S; Priyanka Shinde ***[AIMTDR Conference Proc, Dec 2016, Starting Page 43, Pages 5]*** Additive Manufacturing is identified as a key emerging technology and has received much attention during recent years. Three Dimensional Printing (3D printing) is an Additive Manufacturing (AM) method which finds tremendous applications in industries. Selection of appropriate AM process for an application requires consideration of various conflicting criteria. The right AM option ensures competitive performance of manufacturing which in turn affects quality of the parts. For achieving the best results of any manufacturing process, parametric optimization is essential which has been attempted in the case of 3D printing process using Multi-Criteria Decision Making (MCDM) methods. This paper represents the application of MCDM method i.e. Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) method to optimize the parameters of 3D printing process which takes into account any number of criteria, both quantitative and qualitative, and offer a very simple computational procedure. Three process parameters of FDM based 3D printer are considered in this study which includes layer thickness, build pattern and fill pattern. Response parameters such as surface roughness and building time of part are taken into consideration. Effect of each process parameter on surface roughness and build time has been studied.

111221 Recycling of plastic solid waste for additive manufacturing applications

Rupinder Singh; Narinder Singh; Ahuja, IPS ***[AIMTDR Conference Proc, Dec 2016, Starting Page 27, Pages 3]*** The recycling of plastic solid waste (PSW) is the need of present time because of its nonbiodegradable nature and potential of global warming. Presently, there exist mainly four commercial routes (i.e. mechanical, chemical, energy recovery and extrusion/palletising) for recycling of PSW. However, extrusion/palletising are one of the economical routes for handling small scale plastic waste (SSPW). This paper highlights an alternate route for recycling of PSW in the form of fused deposition modelling (FDM) filament through single screw extrusion process for handling SSPW. Initially high density polyethylene (HDPE) based PSW was collected from plastic recycling plant in granular form. Afterwards a mixture of HDPE/metallic fillers (like: SiC, Al2O3, Fe etc.) was established through melt flow indexing and used for development of alternate FDM filament. Further prepared filament was made to run on FDM machine and prototypes were prepared. The mechanical tests were performed on prototypes to ascertain the

mechanical properties for various additive manufacturing applications.

111222 Experimental investigation on effect of process parameters on tensile strength of 3D printed poly lactic acid specimens

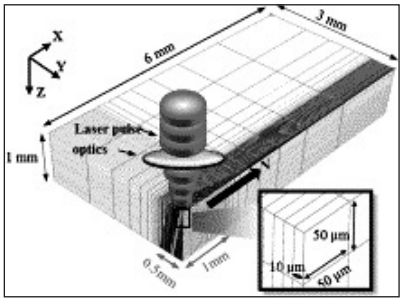
Jayanth, N; Senthil, P; Vinodh, S ***[AIMTDR Conference Proc, Dec 2016, Starting Page 55, Pages 4]*** The Fused Deposition Modelling (FDM) is one of the most commonly used Rapid Prototyping or Additive manufacturing process which uses thermoplastic polymer filaments as raw material and deposit the material in semi molten state on the bed to build the object layer by layer based on CAD model given as input. The purpose of this work is to determine the optimal process parameters that are suitable for the fabrication of components using Poly Lactic Acid (PLA) and also to find out which is the most influencing parameter that affects the mechanical strength. It is biodegradable thermoplastic aliphatic polyester derived from starchy grains like corn, wheat, potatoes, etc. The process parameters which were taken into consideration are the deposition temperature, layer thickness and infill pattern. The nozzle diameter and deposition speed were kept constant. The experiment was carried out using open source 3D printer. 1.75 mm PLA filament is used as raw material and nozzle of 0.4 mm diameter was used. The tensile specimens were prepared as per the standard test method for tensile properties of plastics (ASTM D638-14). An optimization study was performed using Taguchi approach to maximize the mechanical strength and the optimal process parameters to improve the tensile strength were determined. The significant process parameters obtained by analysis of variance (ANOVA) were infill pattern and layer thickness. The optimum conditions are LT2 IP1 T2 i.e. layer thickness of 0.25 mm, rectilinear infill pattern and temperature of 220°C. The maximum tensile strength obtained is 59.103 MPa.

111223 Using Topology optimization to numerically improve barriers to reverse engineering

Devin D. LeBaron and Christopher A. Mattson ***[J of Mechanical Design, v 136, n 2, Feb 2014, Starting Page 021007, Pages 8]*** Here explored is a method by which designers can use the tool of topology optimization to numerically improve barriers to reverse engineering. Recently developed metrics, which characterize the time (T) to reverse engineer a product, enable this optimization. A key parameter used in the calculation of T is information content (K). The method presented in this paper pursues traditional topology optimization objectives while simultaneously maximizing K, and thus T, in the resulting topology. New aspects of this paper include algorithms to (1) evaluate K for any topology, (2) increase K for a topology by manipulating macroscale geometry and microscale crystallographic information for each element, and (3) simultaneously maximize K and minimize structural compliance (a traditional topology optimization objective). These algorithms lead designers to desirable topologies with increased barriers to reverse engineering. The authors conclude that barriers to reverse engineering can indeed be increased without sacrificing the desirable structural characteristic of compliance. This has been shown through the example of a novel electrical contact for a consumer electronics product.

LASER MACHINING

111224 Predictive model and validation of laser cutting of nitinol with a novel moving volumetric pulsed heat flux



Fu, CH; Guo, YB; Sealy, MP ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 2926, Pages 9]*** Nitinol alloys are widely used in manufacturing of cardiovascular stents due to excellent biomechanical properties. Laser cutting is the predominant process for stent manufacturing. However, laser cutting induces thermal damage such as heat affected zone (HAZ), micro cracks, and tensile residual stress, which detrimentally affect product performance. Laser cutting induced temperature distribution, stress development, and HAZ formation are critical process characteristics. However, they are difficult to measure experimentally due to the highly transient process. To better understand the process mechanics in laser cutting of nitinol, a three-dimensional finite element model of pulsed laser cutting was developed to incorporate a novel moving volumetric pulsed heat flux model with high spatial accuracy. A material subroutine was also incorporated to model superelasticity and shape memory of nitinol. The predicted kerf geometry and dimensions agreed well with the experimental data. Also, the effects of cutting speed, pulse power, and pulse width on kerf profile,

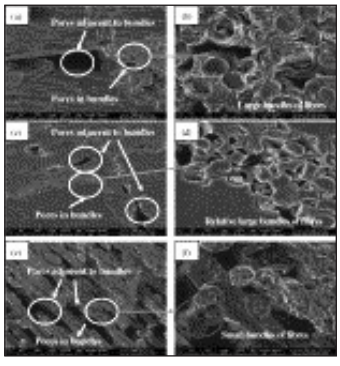
temperature, and heat affected zone (HAZ) were investigated.

MATERIALS & TREATMENT

111225 Influence of pressure and surface roughness on the heat transfer efficiency during water spray quenching of 6082 aluminum alloy

Xu, Rong; Li, Luoxing; Zhang, Liqiang; Zhu, Biwu; Liu, Xiao; Bu, Xiaobing ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 2877, Pages 7]*** The heat flux (q) and heat transfer coefficient (h) at the interface between hot aluminum surface and spray water were determined by using an inverse heat conduction method. Good agreements between numerically calculated temperatures with the inverse identified h and experimentally measurements demonstrate that the method is valid for solving the q and h of spray quenching process. The estimated heat flux consists of three main stages of transition boiling, nucleate boiling and single-phase cooling. The results show that both the heat flux and heat transfer coefficient increase with the increasing of spray pressure. When the surface temperature is lower than 170 °C, the q, h and the maximum heat transfer coefficient (hmax) decrease and then increase as surface roughness increases. However, when the surface temperature is higher than 170 °C, the influence of surface is insignificant. This phenomenon may be attributed to the variation of nucleation site density with surface roughness.

111226 Infiltration mechanism and factors influencing carbon/carbon–Zr–Ti–C composites prepared by liquid metal infiltration

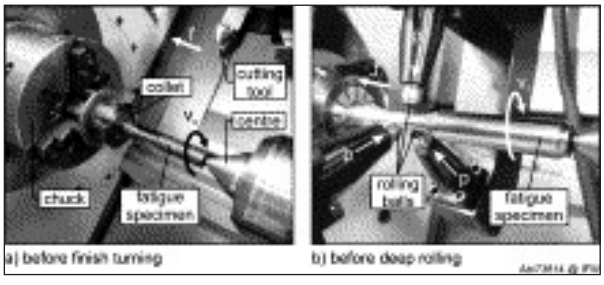


Zeng, Yi; Xiong, Xiang; Wang, Dini; Wu, Liang ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 3150, Pages 8]*** The effects of fibre architecture, reaction temperature and holding time on the infiltration performance of carbon/carbon (C/C)–Zr–Ti–C composites prepared by liquid metal infiltration were investigated. The results indicated that samples with a chopped-web needled preform and low initial density had a high final density. Increasing the reaction temperatures resulted in a decrease of the final density of samples. Additionally, increasing the initial holding time appeared to obviously result in a high final density, but its effectiveness was not obvious in later observations. An analysis of the infiltration kinetics and mechanisms indicated that the diffusivity of carbon in the carbide, the open-pore sizes and their distribution in C/C composites were the essential characteristics that controlled the height of infiltrating melts.

111227 Study on the melting performance of single screw extruder with grooved melting zone and barr screw

Jin, XM; Jia, MY; Xue, P; Cai, J.-Ch; Pan, L; Yu, DQ ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 2834, Pages 9]*** A novel melting mechanism for single screw extruder with grooved melting zone and barr screw was established. The whole solid-plug, which came from the grooved feed zone, was ruptured and melted mainly by continuously changing the volume of the screw channels and the barrel grooves in the grooved melting zone. A new single screw extruder platform with hydraulic-clamshell type barrels was constructed to investigate the melting performance of different combinations of barrels and screws. The melting model was verified by experiments. Compared with conventional single screw extruder, the melting started earlier and the melting length was shorter in the single screw extruder with grooved melting zone. The melting efficiency was improved by the grooved melting zone and the melting stability was improved by the barr screw. The dimensionless analysis of energy indicates that the heat convection and viscous dissipation are the main melting heat sources for the single screw extruder with grooved melting zone.

111228 Influence of heat treatment and deep rolling on the mechanical properties and integrity of AISI 1060 steel



Abrão, AM; Denkena, B; Köhler, J; Breidenstein, B; Mörke, T; Rodrigues, PCM ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 3020, Pages 11]*** This work addresses the influence of distinct microstructures

and deep rolling parameters on the behaviour of AISI 1060 steel. For this purpose, the work material was initially subjected to subcritical and full annealing as well as to hardening through quenching and tempering. The specimens were subsequently deep rolled under different rolling pressures and numbers of passes. The findings indicate that plastic deformation increases with rolling pressure and number of passes due to more intense cold working and that under identical deep rolling conditions the fully annealed material presents more severe deformation than the subcritically annealed samples. Moreover, the ability of deep rolling to increase surface hardness decreases with the elevation of the hardness of the original material. The values of the yield and ultimate tensile strength were affected in different manners by deep rolling depending on work material condition and the tensile residual stresses observed after turning were converted into compressive values by deep rolling. Finally, the elevation of rolling pressure and number of passes presented distinct effects on the microhardness distribution beneath the surface depending on the work material condition.

111229 Influence of heat treatment on tensile properties of LENS deposited Co-Cr-Mo alloy
Mantrala K, Mallik; Srinivasa Rao, Ch; Kesava Rao, VVS ***[AIMTDR Conference Proc, Dec 2016, Starting Page 52, Pages 3]*** Tensile specimens, as per JIS standards, of Co-Cr-Mo alloy are prepared using Laser Engineered Net Shaping (LENS), an additive manufacturing process for metal powders. All the samples are subjected to solution heat treatment at 1200oC for 30, 45 and 60 minutes, followed by water quenching. The samples are divided into three groups. Two groups of samples are aged at 815oC and 830oC for 2, 4 and 6 hours of soaking time. One group of samples is left un-aged. All the heat treatment processes are carried out in controlled atmosphere furnace to avoid oxidation of the material during heat treatment.All the samples are tested for their tensile strength using Instron Tensometer of 5kN capacity. The samples solutionized for 60 minutes without ageing have exhibited highest tensile strengths (both Yield Strength and Ultimate Tensile Strength) among the samples tested. ANOVA has been carried out to understand the influence of heat treatment parameters on the tensile properties of LENS deposited Co-Cr-Mo alloy samples. The tensile properties of the LENS deposited and heat treated samples are observed to be superior to the as-cast Co-Cr-Mo alloy samples.

MEASUREMENT & TESTING

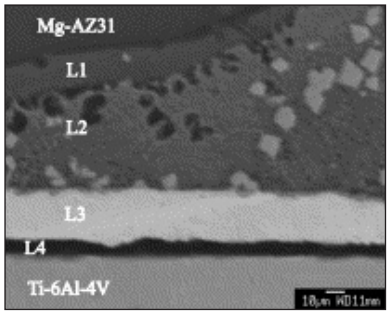
111230 Nonlinear strain energy formulation of a generalized bisymmetric spatial beam for flexure mechanism analysis
Shiladitya Sen and Shorya Awtar ***[J of Mechanical Design, v 136, n 2, Feb 2014, Starting Page 021002, Pages 13]*** Analytical load–displacement relations for flexure mechanisms, formulated by integrating the individual analytical models of their building-blocks (i.e., flexure elements), help in understanding the constraint characteristics of the whole mechanism. In deriving such analytical relations for flexure mechanisms, energy based approaches generally offer lower mathematical complexity, compared to Newtonian methods, by reducing the number of unknowns—specifically, the internal loads. To facilitate such energy based approaches, a closed-form nonlinear strain energy expression for a generalized bisymmetric spatial beam flexure is presented in this paper. The strain energy, expressed in terms of the end-displacement of the beam, considers geometric nonlinearities for intermediate deformations, enabling the analysis of flexure mechanisms over a finite range of motion. The generalizations include changes in the initial orientation and shape of the beam flexure due to potential misalignment or manufacturing. The effectiveness of this approach is illustrated via the analysis of a multilegged table flexure mechanism. The resulting analytical model is shown to be accurate using nonlinear finite elements analysis, within a load and displacement range of interest.

111231 Advanced robust optimization with interval uncertainty using a single-looped structure and sequential quadratic programming
Jianhua Zhou and Mian Li ***[J of Mechanical Design, v 136, n 2, Feb 2014, Starting Page 021008, Pages 11]*** Uncertainty is inevitable and has to be taken into consideration in engineering optimization; otherwise, the obtained optimal solution may become infeasible or its performance can degrade significantly. Robust optimization (RO) approaches have been proposed to deal with this issue. Most existing RO algorithms use double-looped structures in which a large amount of computational efforts have been spent in the inner loop optimization to determine the robustness of candidate solutions. In this paper, an advanced approach is presented where no

optimization run is required for robustness evaluation in the inner loop. Instead, a concept of Utopian point is proposed and the corresponding maximum variable/parameter variation will be obtained just by performing matrix operations. The obtained robust optimal solution from the new approach may be conservative, but the deviation from the true robust optimal solution is small enough and acceptable given the significant improvement in the computational efficiency. Six numerical and engineering examples are tested to show the applicability and efficiency of the proposed approach, whose solutions and computational efforts are compared to those from a previously proposed double-looped approach, sequential quadratic program-robust optimization (SQP-RO).

NANO TECHNOLOGY

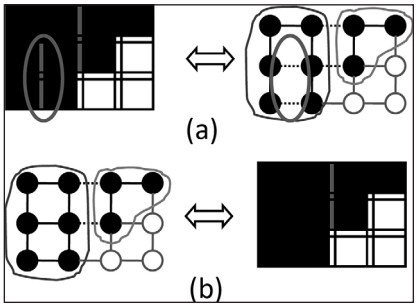
111232 TLP bonding of Ti-6Al-4V and Mg-AZ31 alloys using pure Ni electro-deposited coats.



Atieh, Anas M; Khan, Tahir I ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 3158, Pages 11]*** Transient liquid phase (TLP) bonding of Mg-AZ31 and Ti-6Al-4V alloys was performed using pure thin Ni electro-deposited coat interlayer (12 µm). The effect of bonding temperature, time and pressure on microstructural developments and subsequent mechanical properties across joint interface was studied at a temperature range from 500 to 540 °C, bonding time from 1 to 60 min and bonding pressure from 0 to 0.8 MPa. The mechanisms of bond formation varied across the joint region, with solid-state diffusion dominant at the Ti-6Al-4V interface and eutectic diffusion at the Mg-AZ31 interface. Joint microstructure was examined by scanning electron microscopy (SEM), and energy dispersive spectroscopy (EDS). X-ray diffraction (XRD) was used to detect the formation of intermetallic phases at the fracture surface. The maximum joint shear strength of 61 MPa was obtained at a temperature of 520 °C, 20 min and at a bonding pressure of 0.2 MPa. This joint strength was three times the bond strength reported for joints made using adhesives and represents 50% of the Mg-AZ31 alloy shear strength.

PRODUCT DESIGN & MANUFACTURE

111233 Decomposition templates and joint morphing operators for genetic algorithm optimization of multicomponent structural topology

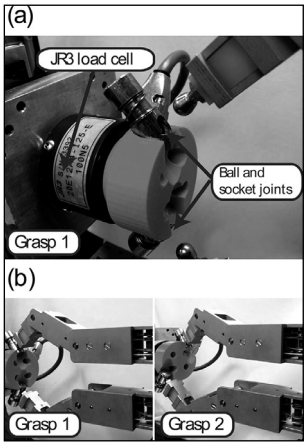


Zebin Zhou, Karim Hamza and Kazuhiro Saitou ***[J of Mechanical Design, v 136, n 2, Feb 2014, Starting Page 021004, Pages 13]*** This paper presents a continuum-based approach for multi-objective topology optimization of multicomponent structures. Objectives include minimization of compliance, weight, and cost of assembly and manufacturing. Design variables are partitioned into two main groups: those pertaining to material allocation within a design domain (base topology problem), and those pertaining to decomposition of a monolithic structure into multiple components (joint allocation problem). Generally speaking, the two problems are coupled in the sense that the decomposition of an optimal monolithic structure is not always guaranteed to produce an optimal multicomponent structure. However, for spot-welded sheet-metal structures (such as those often found in automotive applications), certain assumptions can be made about the performance of a monolithic structure that favor the adoption of a two-stage approach that decouples the base topology and joint allocation problems. A multi-objective genetic algorithm (GA) is used throughout the studies in this paper. While the problem decoupling in two-stage approaches significantly reduces the size of the search space and allows better performance of the GA, the size of the search space can still be quite enormous in the second stage. To further improve the performance, a new mutation operator based on decomposition templates and localized joints morphing is proposed. A cantilever-loaded structure is used to study and compare various setups of single and two-stage GA approaches and establish the merit of the proposed GA operators. The approach is then applied to a simplified model of an automotive vehicle floor subject to global bending loading condition.

111234 Improving process performance of distributed set-based design systems by controlling wellbeing indicators of design actors
Baris Canbaz, Bernard Yannou and Pierre-Alain Yvars ***[J of Mechanical Design, v 136, n 2, Feb 2014, Starting Page 021005, Pages 10]*** In new complex product development processes, the design problem is usually distributed to multiple actors from different disciplines. Each design actor has a limited responsibility in the design system. Therefore, each design actor has limited control over design variables and performance variables. However, design actors are not isolated since their design activities are coupled. This can generate design conflicts through in consistencies among design objectives and working procedures. When the design convergence is not controlled, inconsistencies can distort the satisfaction equilibrium between design actors. This means that if a design actor aims at satisfying only his/her local design objective, other actors having conflicting objectives will be dissatisfied. Thus, individual satisfactions diverge. The intensity of conflicts is measured with the satisfaction divergence. In this paper, we define wellbeing indicators in order to control the convergence of distributed set-based design (SBD) processes. Wellbeing indicators reflect design actors' satisfaction degree of their process desires. We performed a constraint programming Monte Carlo simulation of our SBD framework with a complex design problem. We compared the results of wellbeing indicators with the results of the processes where design actors do not use wellbeing indicators. It is shown that when design actors have some means to control their convergence, the solution space converges to a solution in satisfaction equilibrium while epistemic uncertainty of the design model is reduced. Some conflicts are therefore prevented and the satisfaction divergence is reduced, leading thus to an improved design process performance.

111235 Maximum Confidence Enhancement Based Sequential Sampling Scheme for Simulation-Based Design
Zequn Wang and Pingfeng Wang ***[J of Mechanical Design, v 136, n 2, Feb 2014, Starting Page 021006, Pages 10]*** A maximum confidence enhancement (MCE)-based sequential sampling approach is developed for reliability-based design optimization (RBDO) using surrogate models. The developed approach employs the ordinary Kriging method for surrogate model development and defines a cumulative confidence level (CCL) measure to quantify the accuracy of reliability estimation when Monte Carlo simulation is used based on the developed surrogate model. To improve the computational efficiency, an MCE-based sequential sampling scheme is developed to successively select sample points for surrogate model updating based on the defined CCL measure, in which a sample point that produces the largest CCL improvement will be selected. To integrate the MCE-based sequential sampling approach with RBDO, a new sensitivity analysis approach is developed, enabling smooth design sensitivity information to be accurately estimated based upon the constructed surrogate model without incurring any extra computational costs, thus greatly enhancing the efficiency and robustness of the design process. Two case studies are used to demonstrate the efficacy of the developed approach.

111236 Computational Optimization and Experimental Evaluation of Grasp Quality for Tendon-Driven Hands Subject to Design Constraints



Joshua M. Inouye and Francisco J. Valero-Cuevas ***[J of Mechanical Design, v 136, n 2, Feb 2014, Starting Page 021009, Pages 7]*** The chief tasks of robotic and prosthetic hands are grasping and manipulating objects, and size and weight constraints are very influential in their design. In this study, we use computational modeling to both predict and optimize the grasp quality of a reconfigurable, tendon-driven hand. Our computational results show that grasp quality, measured by the radius of the largest ball in wrench space, could be improved up to 259% by simply making some pulleys smaller and redistributing the maximal tensions of the tendons. We experimentally evaluated several optimized and unoptimized designs, which had either 4, 5, or 6 tendons and found that the theoretical calculations are effective at predicting grasp quality, with an average friction loss in this system of around 30%. We conclude that this optimization can be a very useful design tool and that using biologically inspired asymmetry and parameter adjustments can be used to maximize performance.

111237 Tailoring Strongly Nonlinear Negative Stiffness

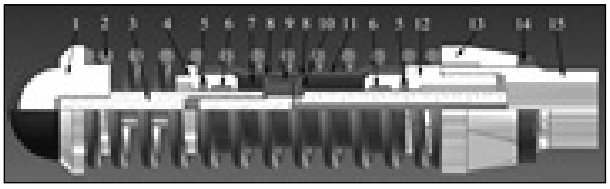
Liu, F; Theodossiades, S; McFarland, DM; Vakakis, AF; Bergman, LA ***[J of Mechanical Design, v 136, n 2, Feb 2014, Starting Page 024501, Pages 7]*** Negative, nonlinear stiffness elements have been recently designed as configurations of pairs or groups of linear springs. We propose a new design of such a system by using a single linear spring with its moving end rolling on a path described by an equation of varying complexity. We examine the effect that the selection of the path has on the size of the deflection regime where negative stiffness is achieved. The stability properties of the equilibrium positions of the system are also investigated, highlighting the influence that the complexity of the path equation brings. The latter naturally affects the characteristics of the forcing functions around these positions. It is demonstrated that the properties of the system can be tailored according to the nature of the equation used and we show how essentially nonlinear negative stiffness elements, (i.e., with no linear parts) can be designed. These results provide a useful standpoint for designers of such systems, who wish to achieve the desired properties in reduced space, which is a common requirement in modern applications.

111238 Modular design approach to improve product life cycle performance based on the optimization of a closed-loop supply chain

Wu-Hsun Chung, Gül E. Okudan Kremer and Richard A. Wysk ***[J of Mechanical Design, v 136, n 2, Feb 2014, Starting Page 021001, Pages 20]*** As environmental concerns have grown in recent years, the interest in product design for the life cycle (DFLC) has exhibited a parallel surge. Modular design has the potential to bring life cycle considerations into the product architecture decision-making process, yet most current modular design methods lack the capability for assessing module life cycle consequences in a supply chain. This paper proposes a method for product designers, called the architecture and supply chain evaluation method (ASCEM), to find a product modular architecture with both low life cycle costs and low energy consumption at the early design stages. ASCEM expands the assessment scope from the product's architecture to its supply chain network. This work analyzes the life cycle costs (LCCs) and energy consumption (LCEC) of two products designated within the European Union's directive on waste of electric and electronic equipment (WEEE) within a closed-loop supply chain to identify the most beneficial modular structure. In addition, data on 27 theoretical cases representing various products are analyzed to show the broader applicability of the proposed methodology. Our analysis shows that ASCEM can efficiently identify a good-quality modular structure having low LCC and LCEC in a closed-loop supply chain for both the two tested products and the hypothetical cases.

ARTIFICIAL INTELLIGENCE & ROBOTICS

111239 Magnetorheologically damped compliant foot for legged robotic application

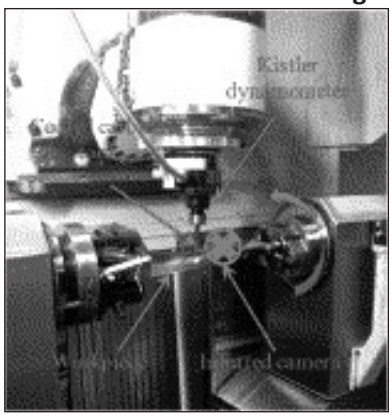


Esa Kostamo, Michele Focchi, Emanuele Guglielmino, Jari Kostamo, Claudio Semini, Jonas Buchli, Matti Pietola and Darwin Caldwell ***[J of Mechanical Design, v 136, n 2, Feb 2014, Starting Page 021003, Pages 11]*** This paper presents an innovative solution for bounce reduction between a robotic leg and the ground by means of a semi-active compliant foot. The aim of this work is to enhance the controllability and the balance of a legged robot by improving the traction between the foot tip and the ground. The compliant foot is custom-designed for quadruped walking robots and it consists of a linear spring and a magnetorheological (MR) damper. By utilizing magnetorheological technology in the damper element, the damping coefficient of the compliant foot can be altered across a wide range without any additional moving parts. The content of this paper is twofold. In the first part the design, a prototype and a model of the semi-active compliant foot are presented, and the performance of the magnetorheological damper is experimentally studied in quasi-static and dynamic cases. Based on the quasi-static measurements, the damping force can be controlled in a range from 15 N to 310 N. From the frequency response measurements, it can be shown that the controllable damping force has a bandwidth higher than 100 Hz. The second part of this paper presents an online stiffness identification algorithm and a mathematical model of the robotic leg. A critical damping control law is proposed and implemented

in order to demonstrate the effectiveness of the device that makes use of smart materials. Further on, drop tests have been carried out to assess the performance of the proposed control law in terms of bounce reduction and settling time. The results demonstrate that by real-time control of the damping force 98% bounce reduction with settling time of 170 ms can be achieved.

TOOLS & TOOLING

111240 Modeling and analysis of coated tool temperature variation in dry milling of Inconel 718 turbine blade considering flank wear effect



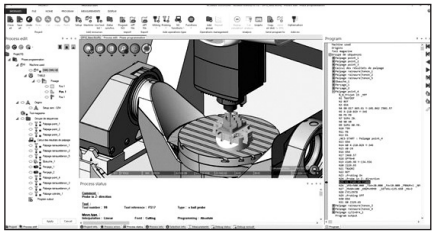
Yan, Sijie; Zhu, Dahu; Zhuang, Kejia; Zhang, Xiaoming; Ding, Han ***[J of Materials Processing Technology, v 214, n 12, Dec 2014, Starting Page 2985, Pages 17]*** This work is motivated by a fact that an excessively worn tool will continue to be used in practical machining of difficult-to-cut materials, such as nickel-based superalloys. Quantitative comparison of worn tool temperature variations with a sharp tool shows great practical significance. A thermal model is presented to describe the coated tool temperature variation in dry milling of nickel-based superalloys for a turbine blade. The influence of flank wear is considered according to the rapid tool wear. In the proposed model, both heat fluxes into the tool from the rake face and due to flank wear are calculated to estimate the tool temperature distribution at different tool states. Feed rate optimization at the convex and concave surfaces of blade based on the force constraints is employed to investigate its influence on heat generation and tool temperature rise. A comparative experiment for dry milling of an Inconel 718 turbine blade is carried out to validate the model. Considering a set of experimental data and the output of the numerical simulations in the present work, a key global heat transfer coefficient (HTC), working as a partitioning coefficient which determines the heat amounts flowing into the chip and the tool, respectively, is assessed through an inverse procedure. This comparison indicates a good agreement in both trends and values. With the alternative method, an accurate simulation of the tool temperature variation can be achieved by the assessed global HTC which is used as an input in the FE model. As the influence of tool wear should be considered, this work can be further employed into the feed rate scheduling guidance in machining complex parts ◘

Six-Axis EDM Drill Also Mills 3D Shapes

EDM Network offers Chmer EDM's six-axis AD5L EDM Drill/Mill, a high-speed EDM drilling machine that can also mill 3D diffuser shapes required for air cooling in jet engines and industrial gas turbine generators. The AD5L can be equipped for fully submerged operation or standard flushing. Also available are a 20-position rotary electrode changer and a guide changer to handle different electrode diameters in one setup.

The EDM's X-, Y- and Z-axis travels measure 500 × 300 × 350 mm, with an optional Z-axis travel of 600 mm also available. The X and Y axes are driven by the Chmer linear motors using Panasonic drives with precision glass scales for positioning accuracy. Submersible A-B index tables are available from MMK, Yukiwa, Parkson, Hirschmann and others. Electrode diameters range from 0.2 to 6.0 mm.

CAM Simulation Software Speeds Turning-to-Milling Turnaround



Spring Technologies offers the latest version (2017) of its flagship software NCSIMUL Solutions and the NCSIMUL 4CAM add-on module. New probing strategies with checking and measurement of intermediary rough stocks enable automatic compensation, taking into account tool wear during machining.

Support for turning after milling enables one-click CNC machine turnaround, the company says. This feature provides automatic reprogramming for all CNC tool and machine changes, delivering flexibility and time savings for CAM programmers and workshop scheduling.

The Optitool option is built into NCSIMUL 4CAM 2017, enabling automation and optimization, especially all rapid motion, with graphic analysis for quick before/after comparison of improvements.

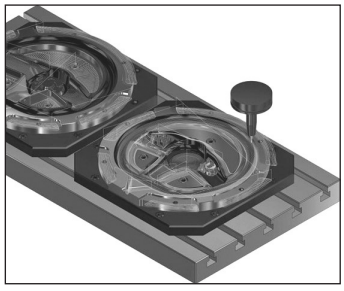
NCSIMUL Tool cutting tool management with 3D definitions, attachments and cutting conditions has been enriched, standardized and stored by material, machine and operation.

This version features one-click project update (phase calculation, simulation and ISO code restart, etc.) and phase export/import to exchange project information with other customer sites or external partners. This enhances inter-company collaboration with subcontractors, suppliers and customers, covering all or part of a project, enabling data exchange and securing the whole project.

Automatic performance analysis of the assembly for five-axis NC machines graphically detects machining risk zones and less-than-optimal cutting conditions.

Three new CAM programs have been added to the list of Workpackages available with NCSIMUL Solutions 2017, including Alphacam, Catia, Cimatron, Creo, Edgecam, Esprit, FeatureCAM, GibbsCAM, HyperMill Mastercam, NX, PowerMill and TopSolid'Cam.

CAM Software Offers Chip Break Settings for Machining Stringy Metals



CNC Software Inc.'s Mastercam 2018 offers several new features and improvements. Stock awareness has been added to select 2D tool paths. The tool motion can now use the top, bottom or both values of the stock, and all the linking parameters can be set to adapt to changing stock values. Finish passes now have more options to choose from. Users can add or remove finish cuts based on the number of rough depth cuts specified on the Depth Cuts page. The workflow for all 3D High Speed tool paths has been streamlined and gives users fine control over exactly where to cut. Users can also assign variable stock to leave values on its walls and floors.

In turning and mill-turn operations, Chip Break is now available for face and finish tool paths when chip breaks occur. The company says this function is valuable when working with stringy materials such as aluminum or plastic, enabling users to set length and time conditions, retract and dwell options. Mill-turn machine definitions now contain tailstock and quill components. The new tailstock operation enables users to define how the machine's tailstock is used, and tailstock options differ depending on the selected machine.

The angle sweep function improves the creation of more complex wireframe functions and, when creating or editing primitives, there are now on-screen sweep and rotate controls which can snap to the AutoCursor positions of existing entities. To make roll and unroll results easier to predict, seam control lets users visually rotate a seam to see how geometry will respond, as well as snap to AutoCursor positions. Hole Axis capability makes it easier to work with a large number of holes, especially holes with matching diameters that are selected as a group.

Additional features include a new set of turning strategies that automate toolpath generation and support for Sandvik Coromant CoroTurn Prime inserts and the PrimeTurning method. The software provides streamlined workflow with improved plane management. Model prep and solid model enhancements such as multiple undo/redo for up to twenty-five functions and more options and controls for solid sweep. The collision control and the multiaxis link safety zone pages for multiaxis tool paths have been redesigned. Common direction has been added to the tool axis control page for multiaxis tool paths and keeps the tool at a uniform tilt angle to reduce tool and machine motion.

Machine Software Speeds 3D Contouring

Makino introduces SGI.5, the latest version of its Super Geometric Intelligence software for high-feed-rate, tight-tolerance machining of complex, three-dimensional contoured shapes. The technology facilitates greater levels of accuracy and reductions in cycle time, the company says. Depending upon the specific geometry of the application, SGI.5 can provide 20 to 60 percent faster cycle times while maintaining accuracy and surface finishes.

The software leverages the rigidity of the Makino machine structure, kinematics of the machine drive systems and the company's latest advancements in servodrive technology. The result is high speeds, high feeds and tight accuracies when executing NC programs with micro-blocks whose traverse movement value is 1 mm or less, the company says. This is characteristic of the complex 3D free, curved surface shapes found in the die/mold, medical, aerospace and other high-performance milling applications.

Tangential Milling Cutter Enables Increased Depths of Cut

Sumitomo Electric Carbide's TSX-series tangential milling cutter is designed for stable, efficient shoulder milling at high feed rates. The TSX is engineered with a tough and sharp cutting edge, and provides the strength required for increased depths of cut ranging from small jobs to heavy-duty roughing applications.

A four-corner ground-tolerance, tangentially-mounted insert with optimized chipbreaker is said to achieve excellent edge sharpness and sidewall accuracy. The TSX is available in two precision-ground insert sizes, offering a maximum depth of cut of 8 or 12 mm (0.315" or 0.473").

Other features of the competitively-priced TSX include reduced cutting force, surface roughness of less than 0.5 micron Ra, squareness less than 0.05 mm and long-term wear resistance.

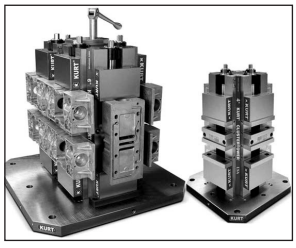
Quick-Change Pallet System Works with Various Table Sizes

Schunk's Vero-S NSL quick-change workholding and positioning system is designed to speed setups with the ability to mount any workholding on top, from a standard vise to a custom fixture, for reliable and consistent change-over. For a micron-precise connection between machine table and

workpiece, the clamping system makes optimal use of even smaller machine tables, the company says. The Vero-S quick-change pallet system delivers fast and precise resetting of workpieces, clamping devices and other equipment on three-, four- or five-axis machining centers.

Workpieces can be directly clamped and machined from five sides without restricting accessibility. This is done by screwing the clamping pins of the quick-change pallet system directly into the workpiece. The components are then quickly exchanged in the machine, positioned, fixed and clamped all in one step with a repeat accuracy of less than 0.005 mm. The clamping height of the workpieces can be adjusted with module height extensions, so the machine spindle can reach all five sides of the workpiece without any special tools.

Hydraulic Workholding Towers Offer as Many as 12 Clamping Stations



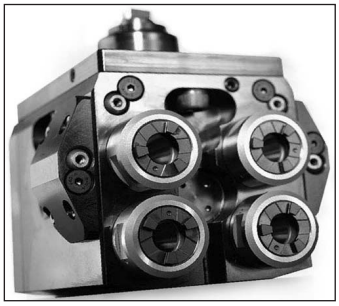
Kurt Workholding offers a complete line of high-density CarvLock workholding towers for precision machining with eight or 12 clamping stations in both manual and hydraulic models. Equipped with easily changeable jaws, these towers provide maximum setup flexibility and fast change-over between jobs, the company says.

The towers are ideal for use on mid-size and larger horizontal machining centers, and options enable configuration to users' exact needs. Each tower station has either a 3" or 4" jaw opening and provides repeatable clamping to 0.0002" with a maximum clamping force of 5,870 to 7,460 lbs, depending on the model.

Self-adjusting holding blocks clamp the similar- or dissimilar-size parts. Fast manual operation is enhanced with the adjustable pre-load feature that reduces handle turns for opening and closing clamping stations. Hydraulic power speeds part clamping by eliminating the need to manually clamp the piece part.

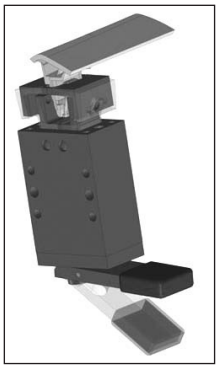
The CarvLock towers are made of ductile iron, maximizing strength, rigidity and long-term accuracy. The elevated column design makes clearing chips and coolant from the clamping area fast and easy. Additional features include jaw options for specific applications such as hard jaws, machinable aluminum and ductile iron jaws, plus aluminum fixture plates. For maximum flexibility, jaws are indexable 180 degrees.

Live Tooling for Popular Series of Turning Centers



Heimatec now offers live tooling for all popular models in the Hyundai, Miyano and Nakamura turning center lines. Standard and custom styles are available for all tapers, including HSK and BT30, as well as fixed and adjustable models.

Clip-Holding, Release Device for Check Fixtures



Fractal Engineering has developed the Clip Buddy, a clip-holding and release device for check fixtures. Suitable for use with W-base plastic clips, steel H-clips, interior or exterior panels, the Clip Buddy can help to overcome the challenge of precisely holding clips in check fixtures and releasing them without damage to the clip, the company says.

The product is significantly smaller than traditional jaw blocks and requires less backside access for actuation. There are several available jaw configurations which can be machined as required for particular applications. The jaws close securely and precisely to enable insertion and holding of a clip for accurate and repeatable inspection of an assembly. To release the clip, the operator actuates the lever with a short and smooth motion to open the jaws; the lever is then actuated in reverse to close the jaws to prepare for loading another part.

End Mills Cut and Polish 2D Contours Simultaneously

Emuge has introduced its Cut & Form solid carbide finishing end mills, designed to perform both cutting and polishing in one operation. The tools' dual functionality is attributed to a design that incorporates three cutting edges to remove material and three burnishing edges to compact the material, producing polished mirror surfaces as fine as 0.08 micron Ra. The tool series is designed to speed throughput and cut back on manufacturing time, secondary operations and cost.

These high-performance tools are ideal for trimming 2D contours in nonferrous materials, such as aluminum and copper, and for the medical, jewelry, food and electronics industries, the company says.

Emuge Cut & Form end mills are available in stub- and standard-length designs, with cutting diameters of 6, 8, 10 and 12 mm.

Modular Connection System for Drilling, Boring, Tapping

Allied Machine & Engineering offers Wohlhaupter's MVS modular connection system. Part of the Multibore collection, the MVS connection is a flexible system designed primarily for drilling and boring, with application possibilities in tapping, end milling and light shell milling.

The MVS connection is a modular connection that enables the use of extended lengths or reduced diameters by using a series of components engineered for flexible adaptation. Four sizes are available to accommodate the diameter range of the boring required: MVS 50-28, 63-36, 80-36 and 100-56. Operators can easily build and change tooling components, and this flexibility enables the system to work accurately for almost any project's needs, the company says.

The MVS connection offers a mating and clamping draw force of approximately 1,900 psi provided by a three-point triangular system. The pressure points are an equal 120 degrees apart, providing high rigidity, high performance capability and a total system accuracy of 3 microns. The system holds tolerances of 0.002 microns ID to OD and a consistent 0.002 microns of parallelism between mating surfaces.

Insert Grade Excels in Turning Uneven Forged Surfaces

Sandvik Coromant has introduced its GC4335 insert grade for the turning of steels where unstable conditions or vibration issues prevail. The grade is designed to provide secure and predictable machining as well as shorter cycle times and better machine utilization through reduced stoppages and longer insert life. Customers will benefit from an improved process with less risk of insert breakage as well as reduced cost per component and faster return on investment, the company says. The grade is said to be particularly good for uneven forged surfaces, the turning of which can lead to frequent insert changes due to fatigue and failure.

GC4335, which features Inveio coating technology for maximum thermal protection, offers greater steel turning endurance through improved edge-line security in comparison with the previous generation of grades, along with greater resistance to flank wear, plastic deformation and crater wear.

The introduction of GC4335 will benefit general engineering shops as well as automotive OEMs and tier suppliers and subcontractors in the oil and gas sector, the company says. Typical components include tubes, valves, crankshafts, differential housings, flanges and rings.

The grade's new substrate balances reliable toughness and resistance to plastic deformation. In addition, a new alumina coating delivers efficient heat transfer from the cutting zone to act as a heat barrier, and the columnar MT-TiCN inner coating offers improved resistance against abrasive wear. A yellow TiN coating on the insert flank eases wear detection ◘

(Source: http://www.mmsonline.com)

Patent Abstracts on Carbon Nanotubes

RU2618278 (C1) 03/05/2017

METHOD FOR PRODUCING A HYBRID MATERIAL BASED ON MULTIWALLED CARBON NANOTUBES REMOTELY DECORATED BY REMOTELY SEPARATED CRYSTALLINE ALUMINIUM NANOPARTICLES

Inventor: OBEDKOV ANATOLIJ MIKHAJLOVICH; KREMLEV KIRILL VLADIMIROVICH; KETKOV SERGEJ YULIEVICH; KAVERIN BORIS SERGEEVICH; SEMENOV NIKOLAJ MIKHAJLOVICH; DOMRACHEV GEORGIJ ALEKSEEVICH

Applicant: FED GOSUDARSTVENNOE BYUDZHETNOE UCHREZHDENIE NAUKI INST METALLOORGANICHESKOJ KHIMII IM G A RAZUVAEVA

FIELD: metallurgy.SUBSTANCE: multiwall carbon nanotubes (MWCN) in powder form 14 are placed in reactor 12, pre-vacuum is created in its volume and the nanotubes are mixed by reverse rotation within 270°. Then, the nanotubes are heated by pyrolysis furnace 15 and vapours of aluminium organometallic compound are supplied-tri-isobutyl aluminium from ampoule 3, heated in evaporator furnace 2 to 50-70°C. As a result of pyrolysis, at temperature 250-300°C, tri-isobutylaluminium decomposes and hybrid material is formed on the basis of MWCN, the surface of which is decorated by remotely separated crystalline alumina nanoparticles. Volatile pyrolysis products are removed from reactor 12 through tube 18 and collected in the trap. Simplified technology for obtaining a hybrid material based on MWCN decorated by remotely separated crystalline aluminium nanoparticles. EFFECT: resulting commercial product requires no additional flushing by solvents and drying. 8 dwg, 8 ex

TW201710183 (A 16/03/2017

GROWTH OF CARBON NANOTUBE (CNT) LEADS ON CIRCUITS IN SUBSTRATE-FREE CONTINUOUS CHEMICAL VAPOR DEPOSITION (CVD) PROCESS

Inventor: HUMFELD KEITH DANIEL

Applicant: BOEING CO

A method and structure for an electrical device and a plurality of electrical circuits including a plurality of carbon nanotubes (CNTs). The method can include forming a first CNT catalyst layer including a plurality of first CNT catalyst plugs, a plurality of electrical circuits electrically coupled to the first CNT catalyst layer, and a second CNT catalyst layer including a plurality of second CNT catalyst plugs electrically coupled to the second CNT catalyst layer. CNTs may be simultaneously formed on the plurality of first and second CNT catalyst plugs within a chemical vapor deposition (CVD) furnace.

KR20160127683 (A) 04/11/2016

METHOD FOR PREPARING MULTIWALLED CARBON NANOTUBES/IONIC LIQUID/MANGANESE NANOHYBRID AND HYDROGEN GENERATION CATALYST BY THE METHOD

Inventor: KIM HERN; AMUTHA CHINNAPPAN

Applicant: MYONGJI UNIV IND AND ACAD COOP FOUND

The present invention relates to a process for producing a multi-walled carbon nanotube / ionic liquid / manganese nanohybrid and a hydrogen-producing catalyst produced thereby, and more particularly to a process for producing a multi-Walled carbon nanotube / ionic liquid / manganese nanohybrid, a multi-walled carbon nanotube / ionic liquid / manganese nanohybrid catalyst, and a method for producing hydrogen using the same. According to the present invention, a multi-walled carbon nanotube / ionic liquid / manganese nanohybrid is simple to manufacture, easy to store, reusable, and rapidly purified. In addition, the catalyst using the multi-walled carbon nanotube / ionic liquid / manganese nanohybrid can perform the catalysis at a low catalyst concentration and temperature in a shorter time than the conventional catalyst.

CN105713235 (A) 29/06/2016

METHOD FOR IMPROVING DISPERSIBILITY OF MULTIWALLED CARBON NANOTUBES IN AQUEOUS SOLUTION

Inventor: XU DAN; WU SHUAISHUAI

Applicant: UNIV SOUTHWEST

The invention relates to a method for preparing aqueous dispersion of multiwalled carbon nanotubes, in particular to a method for improving dispersibility of the multiwalled carbon nanotubes in an aqueous solution. The method includes: taking polyhedral oligomeric silsesquioxane derivatives as a dispersing agent, mixing with the multiwalled carbon nanotubes, and adding a minute quantity of organic reagents to perform wet ball milling; adding

a mixture obtained after ball milling into water according to a certain proportion, and performing ultrasonic treatment to obtain stable aqueous dispersion of the multiwalled carbon nanotubes. The method for improving dispersibility of the multiwalled carbon nanotubes in the aqueous solution aims to solve the problem of difficulty in dispersion of the multiwalled carbon nanotubes in water and is simple in process, efficient, available for mass production and bacially free of structural damages of the carbon nanotubes. The aqueous dispersion of the multiwalled carbon nanotubes is high in stability and especially applicable to the field of preparation of carbon nanotube and hydrophilic superpolymer composite materials and other fields avoiding utilization of a large quantity of organic solvents for dispersion of the carbon nanotubes.

CN105338799 (A) 17/02/2016

NANOCOMPOSITE MADE OF MAGNETIC-METAL-DOPED MULTIWALLED CARBON NANOTUBES/TIN DIOXIDE

Inventor: XING HONGLONG; LIN LING; WANG LEI; LIU ZHENFENG

Applicant: UNIV ANHUI SCI & TECHNOLOGY

The invention discloses a nanocomposite made of magnetic-metal-doped multiwalled carbon nanotubes/tin dioxide, and the nanocomposite can be widely applied to the aspect of electromagnetic wave absorption. A preparation method of the nanocomposite comprises the following steps: 1, conducting acidificaiton on multiwalled carbon nanotubes; 2, dispersing the acidified multiwalled carbon nanotubes treated in step 1 into water, obtaining dispersion liquid of the multiwalled carbon nanotubes, adding tin tetrachloride pentahydrate, then adding nickel nitrate hexahydrate or ferric nitrate nonahydrate or cobalt nitrate hexahydrate, then adding acid, then slowly adding stronger ammonia water, adjusting pH to be 7-10, conducting a reaction for 8-24 hours at the temperature of 120-180 DEG C, and obtaining the nanocomposite made of the magnetic-metal (M)-doped multiwalled carbon nanotubes/tin dioxide through aftertreatment, wherein M represents Fe, Co and Ni, and the massic volume ratio of the acidified multiwalled carbon nanotubes to the tin tetrachloride pentahydrate to the nickel nitrate hexahydrate or the ferric nitrate nonahydrate or the cobalt nitrate hexahydrate to the acid is 0.04 g: 1-4 g: 0.5-3 g: 0.5-4 mL.

KR101578911 (B1) 18/12/2015

LAYER-BY-LAYER ASSEMBLY OF MULTIWALLED CARBON NANOTUBES/TRANSITION METAL NANOPARTICLE MULTILAYERS AND METHOD FOR PREPARING THE SAME

Inventor: CHO JIN HAN; KO YONG MIN

Applicant: UNIV KOREA RES & BUS FOUND

The present invention relates to a method for manufacturing a multi-layered thin film of multi-walled carbon nanotubes and transition metal nanoparticles for a super capacitor electrode. More specifically, the present invention provides a multi-layered thin film electrode having high particle packing density on an organic solvent by using a layer-by-layer assembly method based on covalent bonds using affinity between transition metal nanoparticles, which are stabilized by oleic acid, and an amine group (NH_2).

CN105038229 (A) 11/11/2015

POLYIMIDE HIGH-DIELECTRIC COMPOSITE FILM MIXED WITH MESOPOROUS ALUMINA-LOADED MULTIWALLED CARBON NANOTUBES AND USED FOR CAPACITOR AND PREPARATION METHOD THEREOF

Inventor: TANG BIN; TANG FAGEN

Applicant: TONGLING SHENGDA ELECTRONIC SCIENCE & TECHNOLOGY CO LTD

The invention discloses a polyimide high-dielectric composite film mixed with mesoporous alumina-loaded multiwalled carbon nanotubes and used for a capacitor. By mixing packing such as mesoporous alumina and the multiwalled carbon nanotubes in the polyimide film preparation process and loading the multiwalled carbon nanotubes in mesoporous alumina, the dispersity and utilization rate of the multiwalled carbon nanotubes are improved; coating processing is performed on powder by utilizing a polyvinyl alcohol film having good stability in an organic solvent; and composite powder having undergone silane coupling agent surface modification treatment and organic glue solution are good in interfacial compatibility and are liable to be scattered evenly. Compared with a pure polyimide film, the finally prepared composite film is greatly improved in dielectric properties, still maintains good mechanical properties and processing performance and is good in application prospect.

JP2015174797 (A) 05/10/2015

SUBSTRATE FOR CNT GROWTH, AND PRODUCTION METHOD OF CARBON NANO-TUBE

Inventor: SAKAKIBARA SHINGO; SUZUKI

KATSUNORI; OKUMIYA YASUO; TANITAKA KOJI; SUGIURA MASAHIRO; INOUE TASUKU

Applicant: YAMAHA CORP; UNIV SHIZUOKA NAT UNIV CORP

PROBLEM TO BE SOLVED: To provide a substrate for CNT (Carbon Nano-Tube) growth having excellent uniformity of catalyst density and crystallinity of catalyst, and a production method of a carbon nano-tube using the substrate for CNT growth. SOLUTION: There is provided the substrate for CNT growth which includes at least in one of its surfaces, a catalyst for growing a carbon nano-tube from gaseous starting material containing carbon, and in which the catalyst is formed by vapor deposition of metal contained in a solid source using a hot filament CVD (Chemical Vapor Deposition) method. The hot filament CVD method is performed by using a hot filament CVD apparatus comprising in a decompression chamber, a source part which vaporizes the solid source, a substrate part which heats the substrate on which the catalyst is formed, and a hot filament part which is disposed between the source part and the substrate part, and leads metal-containing vapor vaporized in the source part to the substrate part while heating by hot filament.

IN2621DE2012 (A) 31/07/2015

PROCESS FOR SYNTHESIZING HYBRIDE BIFUNCTIONALIZED MULTIWALLED CARBON NANOTUBES AND APPLICATIONS THEREOF

Inventor: ROY DEBMALYA; SHASTRI BABITA; MUKHOPADHYAY KINGSUK; SAXENA ARVIND KUMAR

Applicant: DIRECTOR GENERAL DEFENCE RES & DEV ORG

The present disclosure provides a process for synthesizing functionalized multiwalled carbon nanotubes (MWCNTs), comprising: refluxing MWCNTs with an acidic mixture to obtain a acid functionalized MWCNTs; and reacting the acid functionalized MWCNTs with oleyl amine in presence of an organic solvent to obtain an oleylamine derivative of MWCNTs. The present disclosure also provides a process for synthesizing a polycarbosilane coated MWCNT, comprising: mixing polycarbosilane and MWCNTs to obtain a mixture; stirring the mixture in Tetrahydrofuran, in presence of a catalyst under an inert atmosphere, to obtain a reaction mixture; and drying the reaction mixture under vacuum followed by heating to obtain polycarbosilane coated MWCNT's. The present disclosure further provides the application of functionalized MWCNTs as synthesized in accordance with the present disclosure, for use in making photovoltaic devices and the application of polycarbosilane coated MWCNTs as synthesized in accordance with the present disclosure for use in making glass fiber reinforced epoxy composites.

CN104559008 (A) 29/04/2015

TERNARY CONDUCTIVE GAS-SENSITIVE SENSING MATERIAL ADOPTING POLYMERS, COMPATILIZER AND MULTIWALLED CARBON NANOTUBES AS WELL AS PREPARATION METHOD AND APPLICATION OF TERNARY CONDUCTIVE GAS-SENSITIVE SENSING MATERIAL

Inventor: LUO YANLING; CAO DAN; BAI RUIXUE; XU FENG

Applicant: UNIV SHAANXI NORMAL

The invention discloses a ternary conductive gas-sensitive sensing material adopting polymers, compatilizer and multiwalled carbon nanotubes as well as a preparation method and an application of the ternary conductive gas-sensitive sensing material. The ternary conductive gas-sensitive sensing material comprises components in percentage by mass as follows: 5%-72% of multiwalled carbon nanotube grafted poly (styrene-tert-butyl methacrylate) copolymer, 13%-45% of carboxylic multiwalled carbon nanotubes and 10%-80% of poly (styrene-tert-butyl methacrylate) copolymer, wherein the compatilizer is prepared from the multiwalled carbon nanotube grafted poly (styrene-tert-butyl methacrylate) copolymer and the poly (styrene-tert-butyl methacrylate) copolymer with a nitroxide-mediated stable free-radical polymerization method, and the conductive gas-sensitive sensing material is prepared with a solution mixing method. The conductive gas-sensitive sensing material has good dispersion stability, can be used for assembling a gas-sensitive sensing film to detect steam of weak-polar organic solvents such as trichloromethane, dichloromethane and tetrahydrofuran, and has the characteristics of high responding sensitivity, good stability, quick response and the like.

CN104448312 (A) 25/03/2015

HIGH-DIELECTRIC-CONSTANT POLYIMIDE FILM PROVIDED WITH MULTIWALLED CARBON NANOTUBES AND PREPARATION METHOD OF HIGH-DIELECTRIC-CONSTANT POLYIMIDE FILM

Inventor: TIAN GUOFENG; SUN YIYI; WANG JUNLI;

LIU JINGNI; QI SHENGLI; NIU HONGQING; HAN ENLIN; WU DEZHEN

Applicant: CHANGZHOU ADVANCED MAT INST OF BEIJING UNIV CHEMICAL TECH

The invention discloses a polyimide film having an outstanding dielectric property and provided with dispersed multiwalled carbon nanotubes and a preparation method of the polyimide film, and belongs to the field of functional high polymer materials. A multiwalled carbon nanotube aqueous dispersion is proportionally added to a polyamide salt solution formed through polycondensation of dianhydride and diamine and complexation of triethylamine and carboxyl, accordingly, a micro-capacitance plate is formed by the carbon tubes in a substrate, and the dielectric property of polymer is improved, wherein the volume fraction of the multiwalled carbon nanotubes is 0.1%-20%. The preparation method mainly comprises three steps as follows: (1), synthesis and salt formation of polyamide acid; (2), solution mixing of the multiwalled carbon tubes and polyamide salt; and (3), thermal cyclization of polyamide acid. According to the polyimide composite film prepared with the method, the dielectric constant of the composite film is greatly increased while original strength and toughness of the polymer are kept as much as possible, the dielectric loss is only slightly increased while compared with the substrate, therefore, the polyimide film has wide application prospect in the material field of the electric and electronic industry.

KR20140121185 (A) 15/10/2014

FABRICATION SYSTEM OF CNT FILTER USING ELECTRO-AERODYNAMIC JET PRINTING, METHOD FOR FABRICATING THE SAME, AND CNT FILTER MANUFACTURED WITH SAID METHOD

Inventor: HWANG JUNG HO ARK KYU TAE

Applicant: UNIV YONSEI IACF

The present invention provides a fabrication system of a CNT filter using electro-aerodynamic jet printing, a fabrication method thereof, and a CNT filter manufactured thereby. The fabrication system of a CNT filter using electro-aerodynamic jet printing is able to conveniently and rapidly perform a fabrication process when compared to a CNT filter manufacture using a conventional chemical vapor deposition (CVD), and to prevent a durability degradation of the filter as the entire fabrication processes are performed at room temperature and normal pressure. The fabrication system of a CNT filter of the present invention comprises: a compressed air supply device to supply compressed air carrying CNT particles; a vaporizing device to flow in the compressed air supplied from the compressed air supply device, and spraying a CNT solution including the CNT particles to vaporize into a CNT gas form; a drying device to remove moisture contained in the CNT gas vaporized through the vaporizing device; a charging device to charge the CNT particles with moisture removed through the drying device to a specific polarity; and a jet nozzle to spray CNT particles onto a filter placed on an electrode substrate applied with a voltage of a polarity opposite to the polarity of the charged CNT particles in a jet flow form to vertically align and print the CNT particles on a textile substrate of a filter by the electric field.

CN103816813 (A) 28/05/2014

ETHYECELLULOSE PERVAPORATION GASOLINE DESULFURIZATION MEMBRANE DOPED WITH MWCNTS (MULTIWALLED CARBON NANOTUBES) AND PREPARING METHOD THEREOF

Inventor: HOU YINGFEI; SHA SHA; HUANG YIQING; LYU HONGLING; LI PENG; SHI DEQING; SUN HAIXIANG; KONG YING

Applicant: UNIV CHINA PETROLEUM

The invention belongs to the field of material processing, and particularly relates to an ethyecellulose pervaporation gasoline desulfurization membrane doped with MWCNTs (multiwalled carbon nanotubes) and a preparing method thereof. The ethyecellulose pervaporation gasoline desulfurization membrane doped with MWCNTs is compounded by an active layer and a base membrane; the active layer is an ethyecellulose membrane doped with MWCNTs, and the base membrane is a polyvinylidene fluoride membrane; the base membrane is coated with the active layer to prepare the ethyecellulose pervaporation gasoline desulfurization membrane.; Reversed shifting occurs in the separation property during the desulfuration of the ethyecellulose pervaporation gasoline desulfurization membrane doped with MWCNTs, provided by the invention, after MWCNTs are subjected to acidizing, the microstructure is greatly improved, hydroxide radicals and carboxy radicals added to the

surface are utilized, oxygen-containing groups are electrophilic groups, can have complex reaction with a sulfocompound as an electronic donor, so that the gasoline desulfurization of an ethyecellulose/MWCNT hybridized blend membrane is further improved.

CN103647047 (A) 19/03/2014

CNT (Carbon Nano Tube)/SnO2 coaxial composite array lithium ion battery negative electrode material

Inventor: DONG SHAOMING; LENG YUE; KAN YANMEI; ZHEN QI; HU JIANBAO; ZHANG XIANGYU

Applicant: SHANGHAI INST CERAMICS

The invention discloses a preparation method of a CNT (Carbon Nano Tube)/SnO2 coaxial composite array lithium ion battery negative electrode material. The method comprises the following steps: firstly pre-depositing an aluminium oxide buffer layer and an iron catalyst layer on a tinsel current collector by utilizing an electron beam evaporation method, growing a CNT array in situ on the current collector by utilizing a hot CVD (Chemical Vapor Deposition) method, and then depositing an atomic layer on the generated CNT array, so as to obtain the CNT/ SnO2 coaxial composite array. Microlitic SnO2 nano tubes are uniformly coated at the outside surface of CNTs, and are firmly combined with the CNTs, and the CNT/SnO2 coaxial material is directly and firmly combined with a metal base. The CNT/ SnO2 coaxial composite array lithium ion battery negative electrode material provided by the invention shows excellent electrical property.

CN103349921 (A) 16/10/2013

Multiwalled carbon nanotubes-polyether sulfone composite filter membrane as well as preparation method and application thereof

Inventor: FAN XIAOJING; HE YAHUI; JIA LI; YANG ZHICHAO; CHU XIAOGANG; GUO HAONAN; PAN CANPING

Applicant: BEIJING CT FOR PHYSICAL & CHEMICAL ANALYSIS

The invention relates to a multiwalled carbon nanotubes-polyether sulfone composite filter membrane as well as a preparation method and an application thereof. The preparation method comprises the following steps of: dispersing multiwalled carbon nanotubes in butyl acetate to form a disperse system; then, on the basis of taking polyether sulfone as a membrane base material, adding a pore-forming agent and N,N-dimethylformamide to form a membrane-forming solution; adding the disperse system in the membrane-forming solution, stirring, and then wiping a membrane on a glass plate; after membrane-forming, evaporating an organic solvent, then placing in water, fishing out and airing, thereby obtaining the multiwalled carbon nanotubes-polyether sulfone composite filter membrane. The composite filter membrane disclosed by the invention is applied to screening for inedible pigments in foods, and used for adsorbing illegally-added pigments in the foods while filtering matrix ingredients in the foods; the pigments are eluted via proper elution solution, and HPLC (high performance liquid chromatography) measurement is performed. The result indicates that the method is simple to operate, rapid and accurate, and capable of repeatedly utilizing the composite filter membrane, thus saving the cost.

WO2013089805 (A2) 20/06/2013

Electrically conducting nanocomposite wire comprising tow of multiwalled carbon nanotubes and transverse metal bridges

Inventor: MUELLER FRED MICHAEL; ROSE CHRIS RANDALL ROSE; MARKEN KENNETH RALPH; DEPAULA RAYMOND F; HOLESINGER TERRY GEORGE

Applicant: LOS ALAMOS NAT SECURITY LLC [US]; MUELLER FRED MICHAEL [US]; ROSE CHRIS RANDALL ROSE; MARKEN KENNETH RALPH ; DEPAULA RAYMOND F; HOLESINGER TERRY GEORGE

Nanocomposite wires having conductivities higher than for metal wires were prepared by pulling tows from a supported array of multi walled carbon nanotubes and sputter depositing metal on the tows, which resulted in transverse bridges between adjacent nanotubes in the tows. These transverse bridges of metal attached adjacent nanotubes to each other and provided paths for electricity to flow from one nanotube to another.

JP2013071876 (A) 22/04/2013

MANUFACTURING METHOD FOR ORIENTED CNT USING WET CATALYST, AND ORIENTED CNT

Inventor: YAMAMURA MASAHIRO; WATANABE YOSHITO; SAKAI TORU; YAJIMA TAKASHI; NAKAYAMA YOSHIKAZU

Applicant: TAIYO NIPPON SANSO CORP;

TECHNOLOGY RES INST OF OSAKA PREFECTURE; UNIV OSAKA PREFECTURE

PROBLEM TO BE SOLVED: To control the size of an oriented CNT to be produced by using a solvent for a catalytic metal salt that gives suitable wettability to a substrate with a reaction preventive film having the reaction preventive film formed on the surface, and forms uniform catalyst layer. SOLUTION: In the manufacturing method, the oriented CNT is synthesized by coating the surface of the substrate with a catalytic metal salt solution obtained by dispersing and/or dissolving the catalytic metal salt in a solvent and heating, followed by thermal CVD treatment, wherein the solvent is a special solvent prepared by mixing PGE and a nonhydrophilic liquid having compatibility with the PGE and non-hydrophilicity. The nonhydrophilic liquid is less subject than the PGE to hydrolysis reaction. The substrate is a substrate with a reaction preventive film having the reaction preventive film formed on the surface of the substrate. A correlation is obtained from the relation between the concentration of the metal salt in the catalytic metal salt solution and the size of the oriented CNT. In the manufacturing method, the concentration of the metal salt is adjusted according to the correlation to control the size of the oriented CNT. ;COPYRIGHT: (C)2013,JPO&INPIT;PROBLEM TO BE SOLVED: To control the size of an oriented CNT to be produced by using a solvent for a catalytic metal salt that gives suitable wettability to a substrate with a reaction preventive film having the reaction preventive film formed on the surface, and forms uniform catalyst layer.SOLUTION: In the manufacturing method, the oriented CNT is synthesized by coating the surface of the substrate with a catalytic metal salt solution obtained by dispersing and/or dissolving the catalytic metal salt in a solvent and heating, followed by thermal CVD treatment, wherein the solvent is a special solvent prepared by mixing PGE and a nonhydrophilic liquid having compatibility with the PGE and non-hydrophilicity. The nonhydrophilic liquid is less subject than the PGE to hydrolysis reaction. The substrate is a substrate with a reaction preventive film having the reaction preventive film formed on the surface of the substrate. A correlation is obtained from the relation between the concentration of the metal salt in the catalytic metal salt solution and the size of the oriented CNT. In the manufacturing method, the concentration of the metal salt is adjusted according to the correlation to control the size of the oriented CNT.

CN102329431 (A) 25/01/2012

PREPARATION METHOD OF EPOXY RESIN COMPOSITE MATERIAL STRENGTHENED BY IN SITU GROWTH OF CNT (CARBON NANO TUBE) ON SURFACE OF QUARTZ FIBRE

Inventor: LING ZHANG; CHUNZHONG LI; LEI JIN

Applicant: UNIV EAST CHINA SCIENCE & TECH

The invention discloses a preparation of an epoxy resin composite material strengthened by in situ growth of CNT (carbon nano tube) on the surface of quartz fiber. The preparation method comprises the following steps of: arranging a layer of catalyst particles on the surface of quartz fiber, and decomposing a carbon source under the catalysis of the catalyst by using a CVD (Chemical Vapor Deposition) method to obtain the quartz fiber with a CNT array evenly growing on the surface; completely mixing epoxy resin and a curing agent under the conditions of ultrasonic oscillation and high-speed stirring; and compounding the quartz fiber with a CNT array evenly growing on the surface and the epoxy resin through VARTM (Vacuum Assisted Resin Transfer Molding).; The interface adhesive strength of epoxy resin with the quartz fiber is improved, and the interlaminar shear strength property of the quartz fiber-CNT/ epoxy resin composite material can be enhanced further.

US2011281204 (A1) 17/11/2011

PREPARATION OF SUPPORTED ELECTROCATALYST COMPRISING MULTIWALLED CARBON NANOTUBES

Inventor: WU GANG; ZELENAY PIOTR

Applicant: WU GANG; ZELENAY PIOTR; LOS ALAMOS NAT SECURITY LLC

A process for preparing a durable non-precious metal oxygen reduction electrocatalyst involves heat treatment of a ball-milled mixture of polyaniline and multiwalled carbon nanotubes in the presence of a Fe species. The catalyst is more durable than catalysts that use carbon black supports. Performance degradation was minimal or absent after 500 hours of operation at constant cell voltage of 0.40 V.

UA92992 (C2) 27/12/2010

PHOTOSENSITIZED MULTIWALLED CARBON NANOTUBES AS ANTITUMOR AGENTS

Inventor & Applicant: PRYLUTSKA SVITLANA

VOLODYMYRIVNA; BURLAKA ANATOLII PAVLOVYCH; LUKIN SERHII MYKOLAIOVYCH; PRYLUTSKYI YURII IVANOVYCH; MATYSHEVSKA OLHA PAVLIVNA

The invention relates to the use of multiwalled carbon nanotubes modified with carboxyl groups irradiated in the near-infrared light area as anticancer agents.

US2010255467 (A1) 07/10/2010

ASSAYS FOR DETERMINING EXPOSURE TO MULTIWALLED CARBON NANOTUBES

Inventor: HOUSTON KEVIN D; PARK MIN SUNG

Applicant: LOS ALAMOS NAT SECURITY LLC

Assays useful in determining exposure to multi-walled carbon nanotubes (MWCNTs) are provided. In one aspect, the MWCNT exposure assays operate by detecting a significant increase in the expression levels and/or status of certain cytokines shown to be responsive to MWCNT exposure.

TW201035544 (A) 01/10/2010

NICOTINE CHEMICAL SENSOR BASE ON MULTIWALLED CARBON NANOTUBES-ALUMINA COATED SILICA MODIFIED GLASSY CARBON ELECTRODE

Inventor: TSAI YU-CHEN; TSAI MING-CHIEH; WANG SHANG-JEN

Applicant: NAT UNIV CHUNG HSING

The patent invention relates to an amperometric sensor for the determination of nicotine. The amperometric sensor for attaching multiwalled carbon nanotube-alumina-coated silica (MWCNT-ACS) composite onto the surface of glassy carbon is describe. The performance of the MWCNT-ACS nanocomposite modified GCE was observed using cyclic voltammetry and amperometry in presence of nicotine. The electrocatalytic activity of MWCNTs towards the oxidation of nicotine has allowed an effective low-potential amperometric determination of nicotine and antisurface fouling effect.

US2010055349 (A1) 04/03/2010

SCANNING PROBE ASSISTED LOCALIZED CNT GROWTH

Inventor: GAITAS ANGELO; MITRA BHASKAR; BASU AMAR; ZHU WEIBIN

Applicant: GAITAS ANGELO; MITRA BHASKAR; BASU AMAR; ZHU WEIBIN; PICOCAL, INC

The present invention is a method for localized chemical vapor deposition (CVD) for localized growing for example for carbon nanotubes (CNT), nanowires, and oxidation using a heated tip or an array of heated tips to locally heat the area of interest. As the tips moved, material such as CNTs grows in the direction of movement. The Scanning Probe Growth (SPG) or nanoCVD technique has similarities to the CVD growth; however it allows for controlled synthesis and direction and eliminates the need for masks.

KR20060115267 (A) 08/11/2006

SULFUR ELECTRODE USING MULTIWALLED CARBON NANOTUBES AND GRAPHITIC NANOFIBES FOR LITHIUM/SULFUR BATTERY

Inventor: KIM KI WON; AHN HYO JUN; AHN JOU HYEON; NAM TAE HYUN; CHO KWON KOO; CHO GYU BONG; KIM JONG UK; CHUNG YOUNG DONG; KIM JONG HWA; JEONG SANG SIK; CHOI YOUNG JIN; PARK SANG CHEOL; KIM SUNG HYUN; RYU HO SUK; KIM TAE BUM; SHIN WON CHEOL; LEE BONG KI; KANG SEUN GOO; HA JONG KEUN; KIM SANG SUK; CHOI JAE WON; KIM YEON WHA; KIM JAE KWANG

Applicant: IND ACADEMIC COOP

Provided is a sulfur electrode for a lithium/sulfur secondary battery, which has a stable structure and a high specific surface area, shows high initial capacity and improved cycle characteristics, and maximizes the efficiency of a lithium/sulfur secondary battery. The sulfur electrode for a lithium/sulfur secondary battery comprises multiwalled carbon nanotubes(MWNT) or graphitic nanofibers(GNF) as a conductive additive. The additive includes a carbon nanomatrix. The additive is added in an amount of 20-50 wt% based on the weight of a conductive agent. The sulfur electrode is formed of S, NaS, FeS, FeS2, NiS, CuS or a combination thereof. The sulfur electrode is obtained by a magnetic stirring process, an attrition ball mill process or a combination thereof.

FR2880200 (A1) 30/06/2006

THIN WAFER E.G. SILICON WAFER, FOR FUEL CELL, HAS SET OF THOROUGH HOLES WHICH ARE FILLED WITH CONDUCTIVE CARBON NANOTUBES THAT ARE ORIENTED TRANSVERSALLY TO SURFACE OF WAFER, WHERE NANOTUBES ARE MULTIWALLED TYPE

Inventor: ROY MATHIEU; PIERRE FABIEN

Applicant: ST MICROELECTRONICS SA

The wafer has a set of thorough holes which are filled with conductive carbon nanotubes (22, 23) that are oriented transversally to a surface of the wafer. An insulating layer is formed between the carbon nanotubes and walls of the holes. The nanotubes are of multiwalled type and

surrounded with carbon nanotube strips (26, 27, 28, 29). The nanotubes are coated or impregnated with a catalyst e.g. platinum. Independent claims are also included for the following: (A) a fuel cell comprising a thin wafer (B) a method for manufacturing a fuel cell.

JP2005322646 (A) 17/11/2005

METHOD OF MANUFACTURING CNT FIELD EMISSION ELEMENT

Inventor: JEONG TAE-WON; HUR JUNG-NA; LEE JEONG-HEE

Applicant: SAMSUNG SDI CO LTD

PROBLEM TO BE SOLVED: To provide a method of manufacturing CNT (Carbon Nano Tube) emitter capable of reducing thermal shock to an element in high temperature process. ;SOLUTION: Pulverized CNT is adhered to a first substrate, a metal is vapor-deposited on the surface of the CNT and this is pressure contacted to a surface of a negative electrode. After pressure contacting, the first substrate is isolated from a second substrate to primary stretching the CNT, thereby arranging the CNT perpendicular to the substrate. The CNT emitter perpendicular to the substrate is manufactured without using CVD by this method. The manufactured CNT emitter has excellent electrical characteristics and very high purity

US2005002850 (A1) 06/01/2005

METHODS OF OXIDIZING MULTIWALLED CARBON NANOTUBES

Inventor: NIU CHUNMING; MOY DAVID; CHISHTI ASIF; HOCH ROBERT

Applicant: HYPERION CATALYSIS INT

Methods of oxidizing multiwalled carbon nanotubes are provided. The multiwalled carbon nanotubes are oxidized by contacting the carbon nanotubes with gas-phase oxidizing agents such as CO2, O2, steam, N2O, NO, NO2, O3, and ClO2. Near critical and supercritical water can also be used as oxidizing agents. The multiwalled carbon nanotubes oxidized according to methods of the invention can be used to prepare rigid porous structures which can be utilized to form electrodes for fabrication of improved electrochemical capacitors.

US2004022719 (A1) 05/02/2004

PROCESS FOR THE MASS PRODUCTION OF MULTIWALLED CARBON NANOTUBES

Inventor: BEGUIN FRANCOIS; DELPEUX SANDRINE; SZOSTAK KATARZYNA

Applicant: BEGUIN FRANCOIS; DELPEUX SANDRINE; SZOSTAK KATARZYNA; CNRS

The present invention concerns a process for the mass production of carbon nanotubes and particularly a process for selectively producing multiwalled carbon nanotubes.

JP2003206116 (A) 22/07/2003

RADIAL CLUSTER OF SHARP-ENDED MULTIWALLED CARBON NANOTUBES AND METHOD FOR PREPARING THE SAME

Inventor: IIJIMA SUMIO; YUDASAKA MASAKO; KOSHIO AKIRA

Applicant: JAPAN SCIENCE & TECH CORP; NEC CORP

PROBLEM TO BE SOLVED: To provide radial clusters of sharp-ended multiwalled carbon nanotubes, which are new carbon nanostructures useful as a probe for STM (scanning tunneling microscope) or AFM (atomic force microscope), a field emission electron source of a display element, a display, or the like, and to provide a method for preparing the radial clusters. ;SOLUTION: A plurality of sharp-ended multiwalled carbon nanotubes whose one side ends are each at a sharp angle are radially clustered with the sharp ends outward to obtain the objective radial clusters of sharp-ended multiwalled carbon nanotubes.

JP2003206117 (A) 22/07/2003

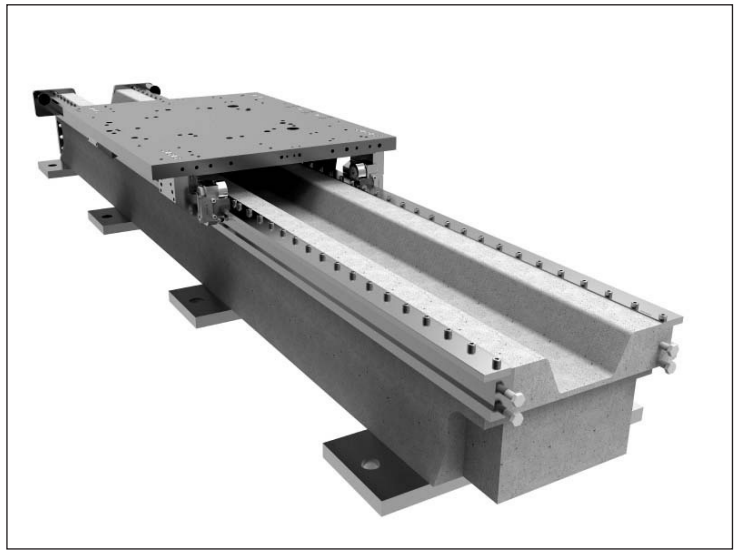
PROCESS FOR MASS PRODUCTION OF MULTIWALLED CARBON NANOTUBES

Inventor: FRANCOIS BEGIN; SANDRINE DERUPO URUDORIAN; KATARZYNA SHOSTAK

Applicant: CENTRE NAT RECH SCIENT

PROBLEM TO BE SOLVED: To provide a process for the selective mass production of multiwalled carbon nanotubes. ;SOLUTION: This process for the selective mass production of multiwalled carbon nanotubes from the catalytic decomposition of hydrocarbons comprises the in site reduction of a non-previously reduced and nonsupported precursor of a supported metallic catalyst under conditions enabling the in site production of the catalyst and the production of the nanotubes, and the following recovery of the nanotubes. Particularly, the process is carried out at 500-900°C and the hydrocarbons are diluted in a carrier gas ◘

IPR Develops World First: 7th Axis Made of Concrete Instead of Metal



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(Source: https://www.iprworldwide.com/en/news-single-view/artikel/ipr-develops-world-first-7th-axis-made-of-concrete-instead-of-metal.html)

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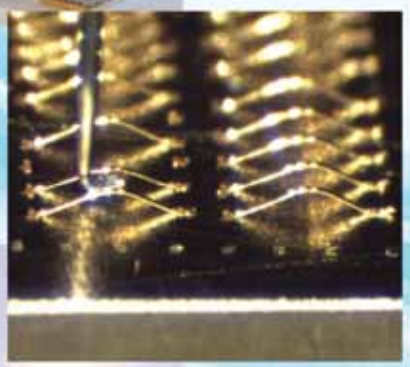

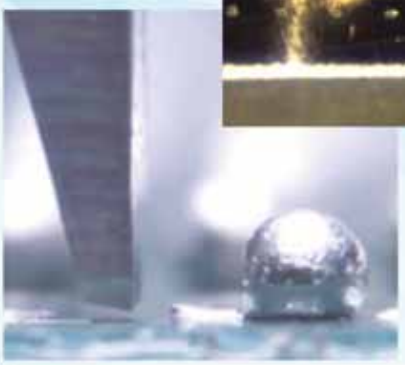

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