CHAPTER 5

Material Characterization

5.1 TENSILE PROPERTIES OF EDD STEEL

Since the process was mathematically modeled which requires the properties the EDD steel like yield strength, ultimate tensile strength, strength coefficient, work hardening exponent and percentage elongation at various temperatures. So experiments were conducted on a 50 kN electronically controlled UTM. The experiments were conducted at a constant crosshead speed of 2 mm/min. This is to avoid the effect of variable strain rate on the mechanical properties of the material. The experiments were conducted from room temperature to 700^0 C in the steps of 25^0C. The specimens were cut and machined according to DMRL specifications along axis parallel, diagonal and perpendicular to the rolling direction. Total 28 sets (84 tests) were conducted at different temperatures to find out mechanical properties of the material. Figs 5.1-5.5 elaborate the experiment results.

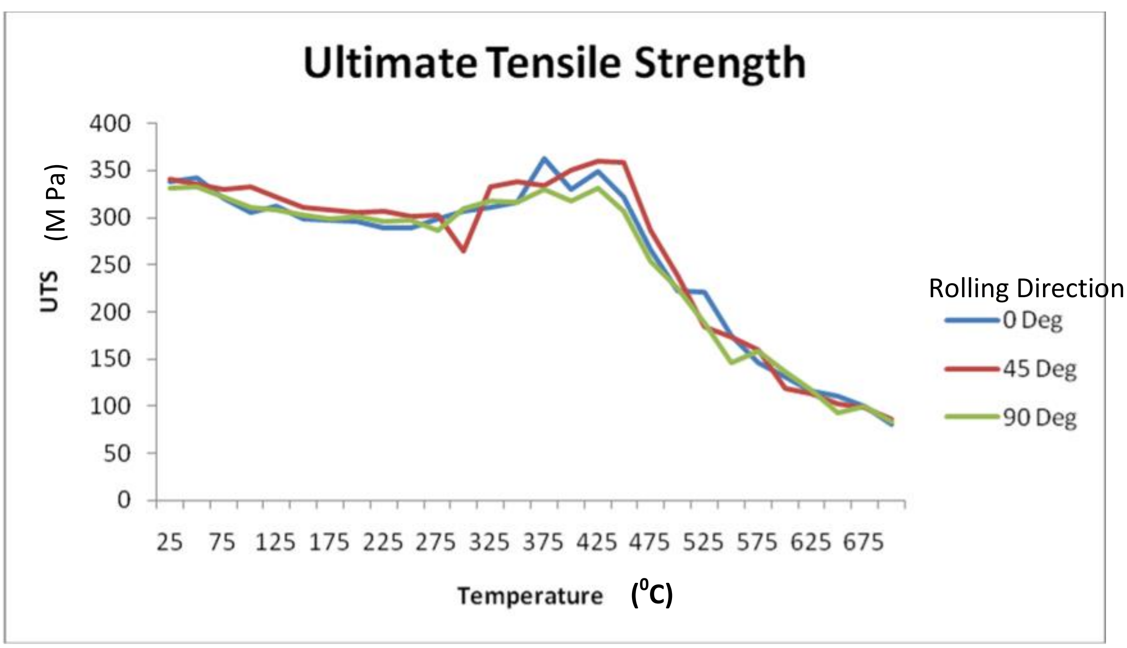

Fig 5.1 Ultimate tensile strength Vs Temperature at various orientations

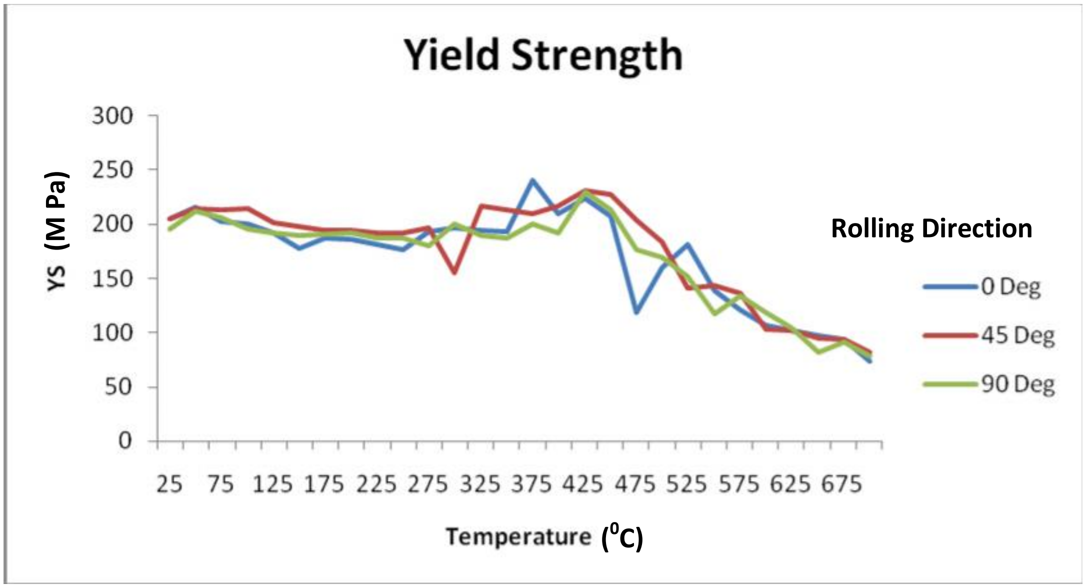

Fig 5.2 Yield strength Vs Temperature at various orientations

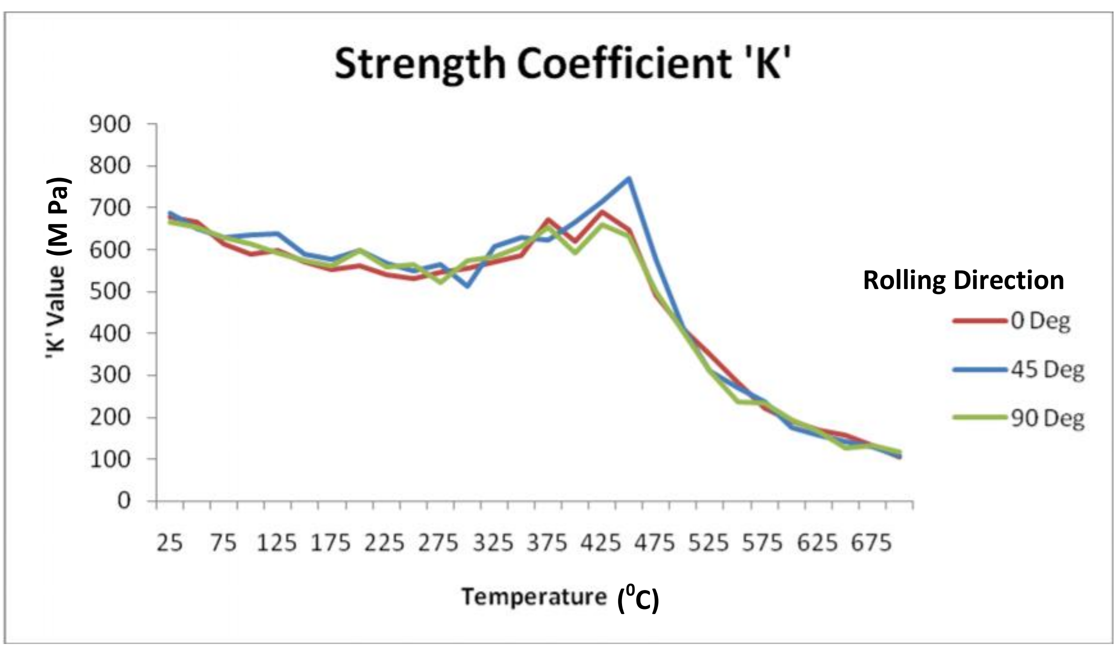

Fig 5.3 Strength coefficient ‘ K’ Vs Temperature at various orientations

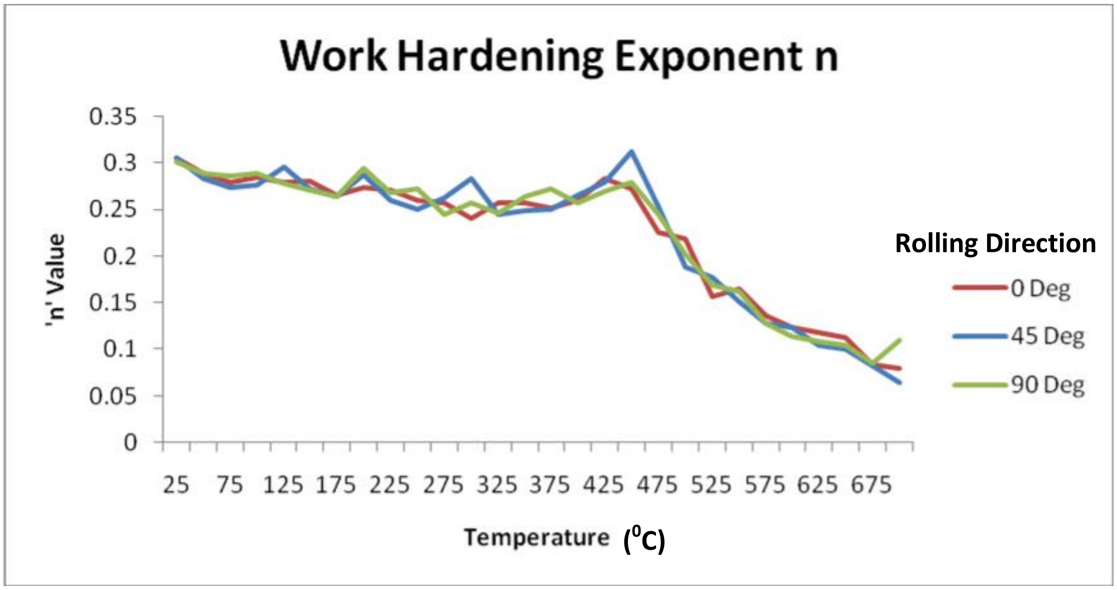

Fig 5.4 Work hardening Exponent 'n' Vs Temperature at various orientations

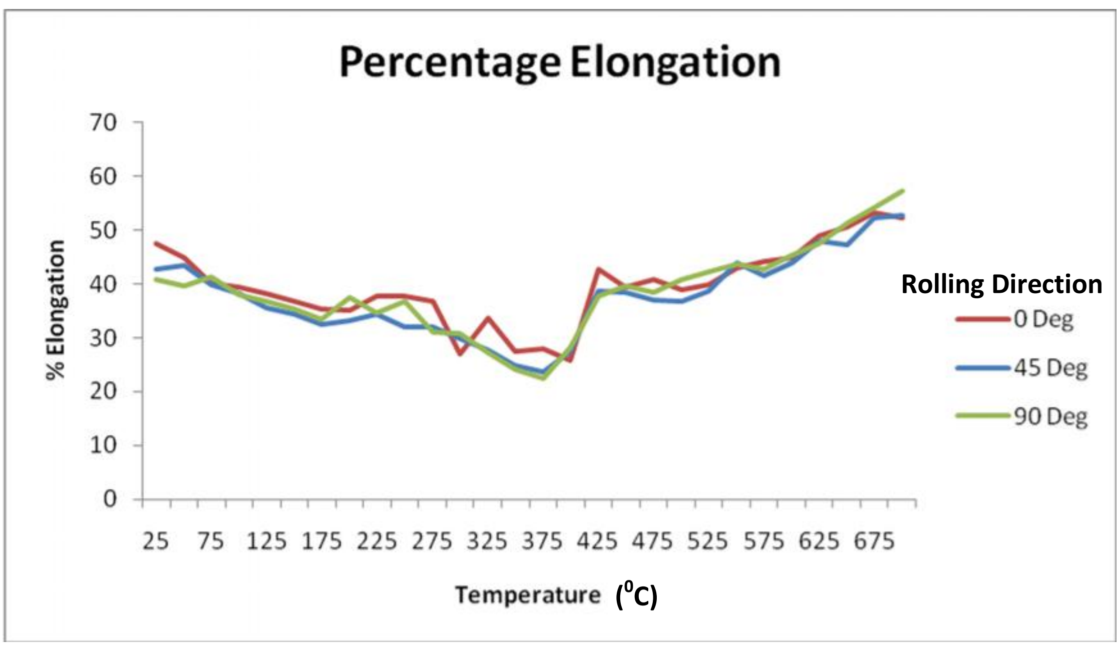

Fig. 5.5 Percentage Elongation' Vs temperature at various orientations

It can be observed from these figures that properties of material change the trend in the temperature range of 350^0C to 450^0C. This is primarily due to blue brittle phenomenon that appears between 350^0C to 450^0C. Later the material enters into the plastic range. Beyond 450^0C, since the material enters into plastic range, percentage elongation increases and strength properties such as yield stress, UTS, Work hardening exponent 'n', Strength coefficient 'K' decrease by increasing temperature. So, these sheets are expected to have good formability at elevated temperatures because not only there is decrease in the flow stresses at higher temperature but also increase in the percentage elongation. Higher strain hardening exponent (n) increases the ability of the metal to undergo uniform plastic deformation before localized necking/excessive thinning. Dynamic strain aging (DSA) in solid solutions is described as diffusion of solute atoms to mobile dislocations, temporarily arrested at obstacles. As a consequence the solute concentration experienced locally by the dislocations depends on the time of arrest and the solute diffusion coefficient. DSA is manifested by a negative strain rate sensitivity, which results in unstable, jerky flow [Fig 5.6]

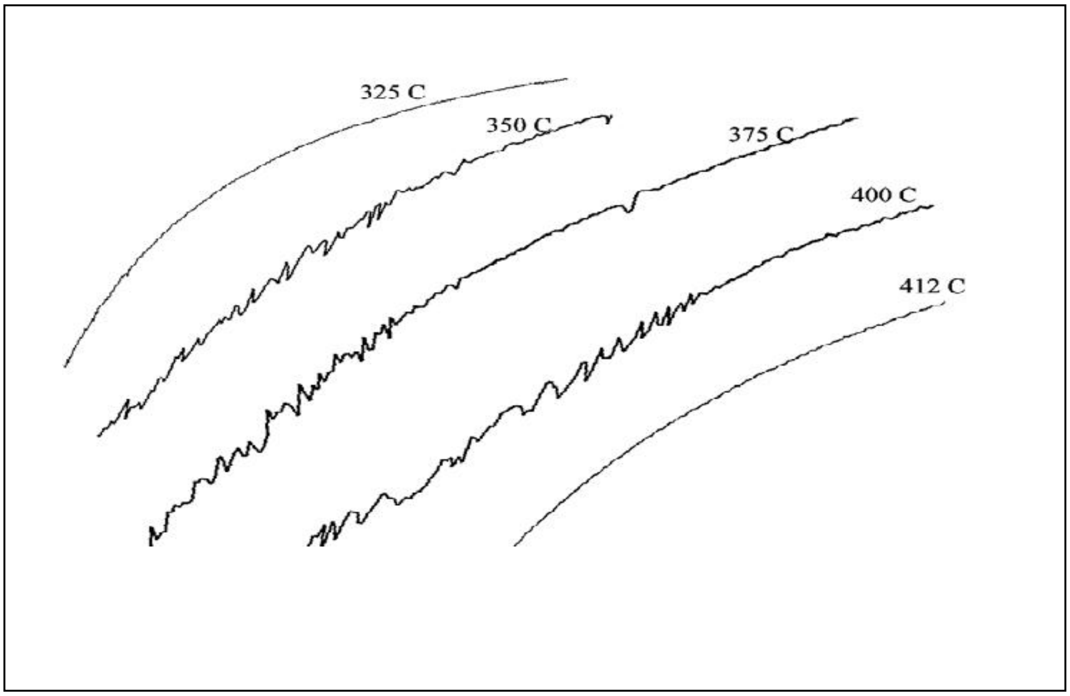

Fig. 5.6 Serrations due to DSA explaining Blue brittle phenomenon

The consolidated data of average values of different tensile properties are given in the Table 5.1

Table 5.1 Average values of Tensile Properties at various temperatures

TEMPERATURE (^0C)	UTS (M Pa)	YS (MPa)	STRAIN AT YS	ELG (%)	STRENGTH COEFFICIENT (K) (MPa)	WORK HARDENING EXPONENT (n)
25	337	202	0.0222	44	677	0.304
50	337	214	0.0317	43	657	0.287
75	324	208	0.0304	40	624	0.280
100	316	203	0.0237	38	613	0.283
125	314	195	0.0276	37	610	0.285
150	304	188	0.0291	35	577	0.274
175	302	191	0.0291	34	564	0.265
200	301	191	0.0310	35	586	0.286
225	297	187	0.0277	36	556	0.267
250	296	185	0.0231	35	547	0.261
275	296	190	0.0276	33	544	0.255
300	294	184	0.0314	29	548	0.261
325	321	200	0.0416	29	588	0.250
350	324	198	0.0358	26	608	0.257
375	343	217	0.0365	25	649	0.258
400	333	206	0.0398	27	626	0.261
425	347	228	0.0483	40	688	0.278
450	329	216	0.0582	39	684	0.289
475	269	166	0.0387	39	522	0.242
500	229	171	0.0208	39	410	0.203
525	198	158	0.0391	40	323	0.167
550	164	133	0.0192	44	264	0.159
575	155	131	0.0193	43	231	0.130

Contd....

TEMPERATURE (0C)	UTS (M Pa)	YS (MPa)	STRAIN AT YS	ELG (%)	STRENGTH COEFFICIEN T (K) (MPa)	WORK HARDENING EXPONENT (n)
600	128	110	0.0178	45	187	0.120
625	115	103	0.0241	48	164	0.110
650	101	91	0.0213	50	143	0.105
675	110	93	0.0870	52	168	0.142
700	83	78	0.0940	54	110	0.084

5.2 SCANNING ELECTRON MICROGRAPH STUDY

Scanning electron micrographs (SEM) are generally used to see the fracture behavior in the materials. In the present research, once the specimen is fractured on UTM machine, it is cut at the fracture point with the help of a wire cut EDM. This process is used primarily to keep the fracture area safe for the study.

Fractographs are prepared at room temperature, in the dynamic strain regime (400^0 C) and in the plastic region at 700^0 C. These fractographs are magnified at the centre and at the edge which are shown in Figs. 5.7-5.9. It can be seen from Fig. 5.7 that there are large number of craters both at the centre and near the edge, so it is cup and cone ductile fracture as expected in EDD steel samples. These craters appear uniformly in the entire region of fracture. From the fractograph of the sample in the dynamic strain regime (Fig 5.8) it can be seen that it is a cleavage type fracture. So the primary mode of fracture of EDD in this region is brittle fracture. From the micrograph [Fig. 5.9] of specimen at 700^0 C it can be seen that in this region fracture mode is again primarily ductile.

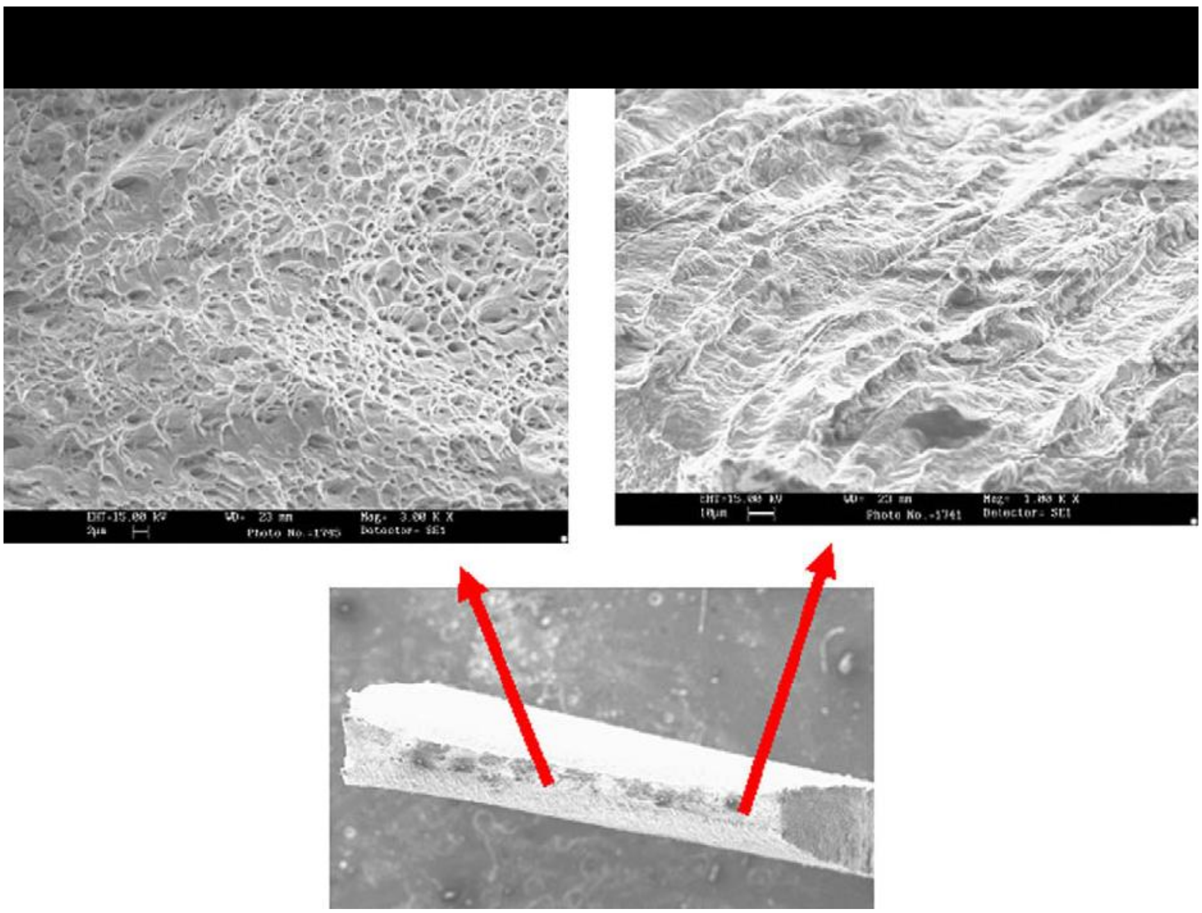

Fig 5.7 SEM images at fractures surface of UTM specimen at 25^0C)

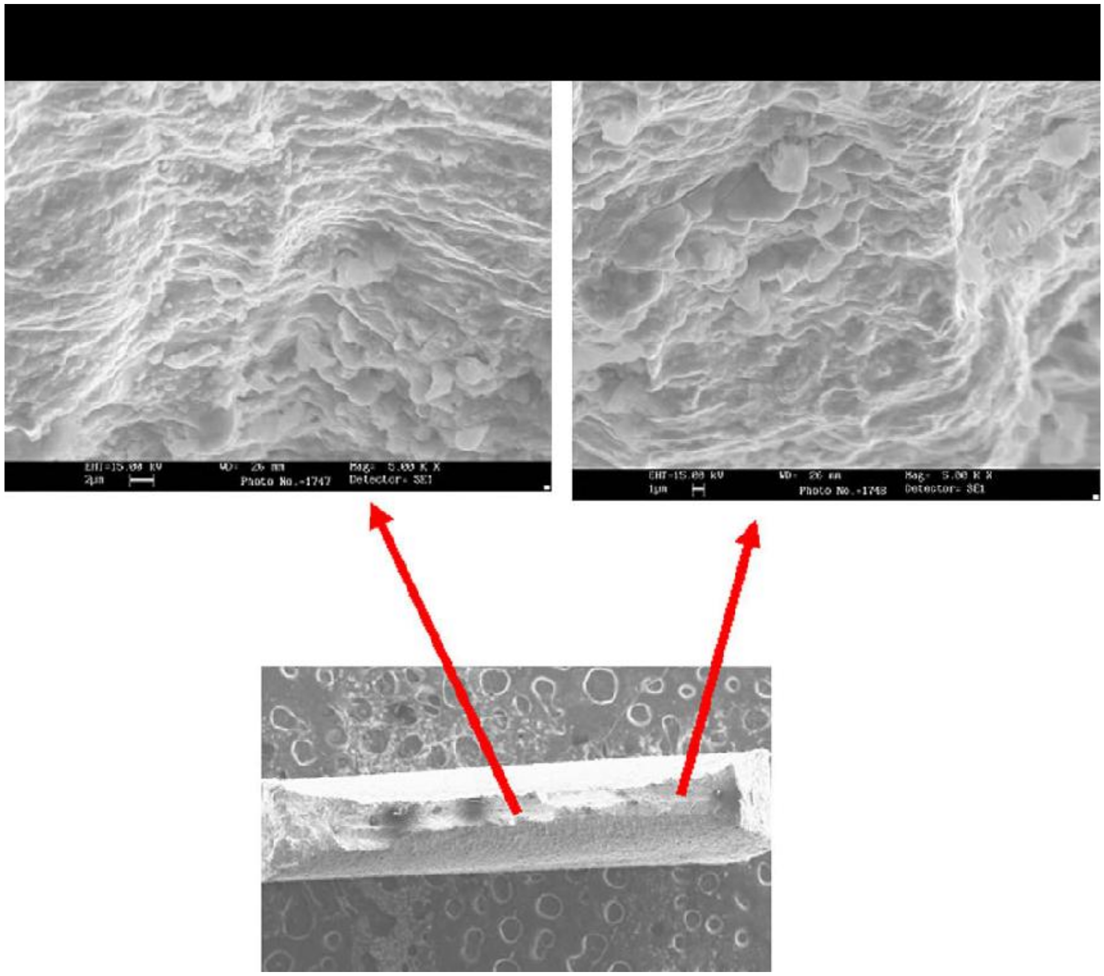

Fig 5.8 SEM images at fractures surface of UTM specimen in dynamic strain regime (400^{0}C).

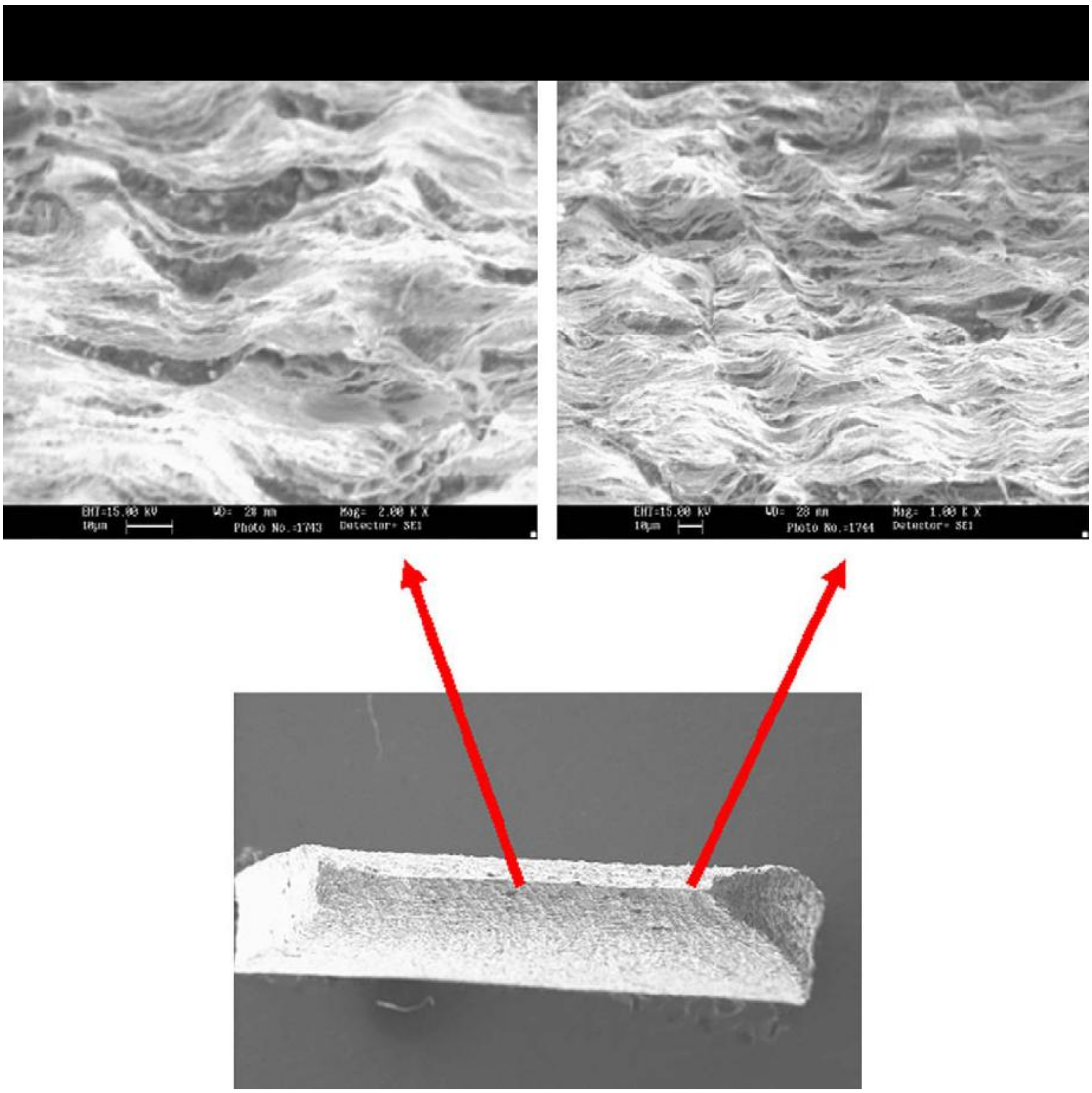

Fig 5.9 SEM images at fractures surface of UTM specimen in plastic region (700^{0}C).