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BOLTED JOINTS AS ROOT CAUSES OF EQUIPMENT FAILURE[1]

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Abstract
The work presents a general view of the bolted joint problems faced by ArcelorMittal Tubarão in the last years, as well as the solutions adopted. A deeper analysis demonstrated the great participation of the bolts in the basic causes representing about 37% of the occurrences / failure. Several actions have been taken to correct the problems, divided into management and techniques. This work represents all the effort developed by ArcelorMittal Tubarão to eliminate the influence of the bolted joint as a basic cause of equipment failure, contributing to its availability and the excellence of maintenance in the company.
Key words: Bolted joints; Bolt; Torque; Fixing elements.

UNIÕES PARAFUSADAS COMO CAUSA BÁSICA DE FALHAS EM EQUIPAMENTOS

Resumo
O trabalho apresenta uma visão geral dos problemas relacionados a uniões parafusadas enfrentados pela ArcelorMittal Tubarão nos últimos anos, bem como as soluções adotadas. Uma análise mais profunda demonstrou a grande participação dos parafusos nas causas básicas representando cerca de 37% das ocorrências, seja decorrente da montagem inadequada, falha de projeto, fornecimento incorreto, falhas na inspeção, etc. Diversas medidas adotadas para a correção dos problemas são descritas e analisadas. Esse trabalho apresenta todo o esforço desenvolvido pela ArcelorMittal Tubarão para eliminar a influência das uniões parafusadas como causa básica de falhas, contribuindo na excelência da manutenção mecânica na empresa.
Palavras-chave: Uniões parafusadas; Torque; Parafusos; Elementos de fixação.

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1 INTRODUCTION

Bolted joints are one of the most common elements in construction and machine design. They consist of cap screws or studs that capture and join other parts, and are secured with the mating of screw threads.(1)
Proper bolting is a fundamental requirement of equipment reliability, but it is often ignored. There is nothing impossible about proper bolting techniques. It is simply a matter of proper fastener selection, installation and periodic inspection.
The work presents a general view of the bolted joint problems faced by ArcelorMittal Tubarão in the last years, as well as the solutions adopted. A study accomplished in 2005 correlated to the equipment flaws and the mechanical components involved led to the conclusion that the bolted joint was the item with the highest frequency of occurrences.
A deeper analysis demonstrated the great participation of the bolts in the basic causes representing about **37% of the occurrences / failure**.

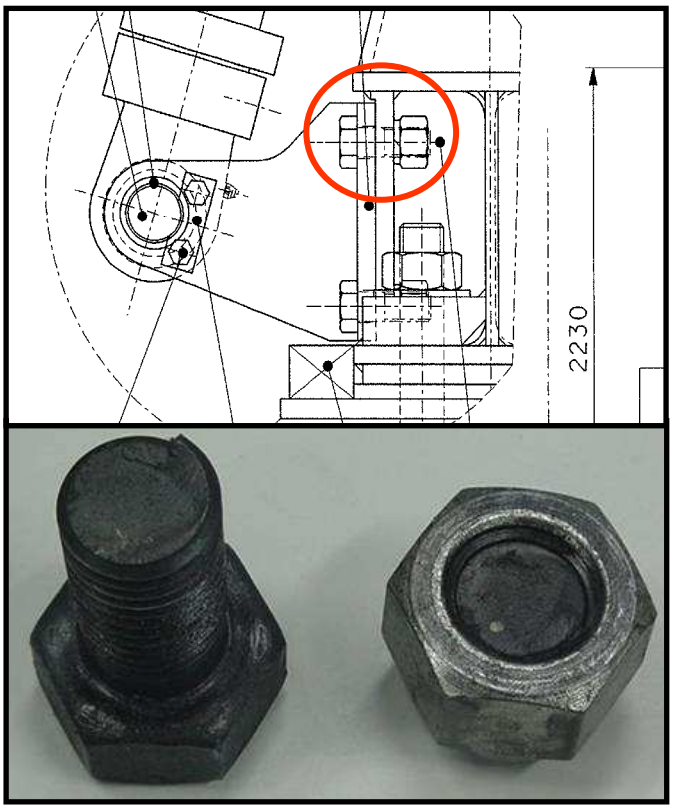

Figure 1 – Bolted joints failure.

2 METHODOLOGIES - TYPES OF BOLTED JOINT FAILURES

A complete analysis of equipment failure was carried out and the root cause was found to be the elements of the bolted joint (bolt, nut and washer). It indicated improper assembly, design flaw, incorrect supply, mistakes in the inspection and others. Several actions have been taken to correct the problems, divided into management and techniques.
"Some of the great projects depend on the success of the small details". That popular proverb highlights the importance of small details and how they make a difference.

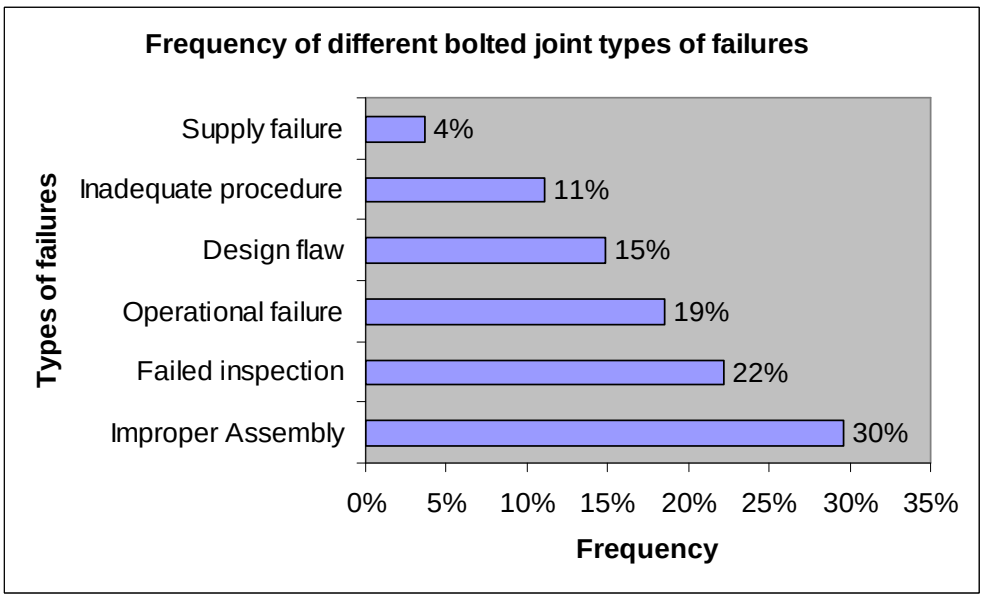

Figure 2 – Chart of frequency bolted joint failure.

Improper bolting has the biggest **impact on the machine reliability and life cycle cost.** If bolted joint are not properly installed, it can cost thousands to replace them and their associated parts. A simple change in bolting procedures generated more positive changes in reliability and life cycle cost than any other single maintenance practice.

3 BOLTED JOINT SOLUTIONS

Bolting techniques is a matter of proper fastener selection, installation and periodic inspection.[2] The following are the main solutions adopts by ArcelorMittal Tubarão.

3.1 Creation of Internal Standards and Norms

AM Tubarão had to develop a specific documentation of the proper bolted joint installation procedure for each joint location, like the standards PT-MAN-GMAN-01-0001 and B8210MX06423.[3]

3.2 Complete Revision of the Purchasing Procedure

All fasteners are not the same. Each application has specific requirements such as torque, weight, vibration, etc. that determines the type or grade of fastener required. It is necessary create standards to purchasing bolts, nuts and washer according its application. Follow these requirements without exception. Failure to do so reduces machine reliability and increase maintenance costs.

3.3 Complete Revision of Supply Chain

The supply chain has been revised to avoid material failures or manufacturing problems. Only the two better suppliers were selected to guaranty the quality of bolted joint elements like bolts, nut and washer.

3.4 Intensive Internal Courses and Training

AM Tubarão invested in internal training and quality control measure to ensure that the documentation procedure is followed carefully and precisely every time the bolted joint is changed. In 2007, approx 140 technicians were trained.

3.5 Use of Flat Washer

Another prevalent problem is the misuse of washers. This is especially true of split-ring or helical spring lock washer. Most applications only require flat washer which are designed to distribute bolting pressure and machine load uniformly. However the washer must be selected and installed properly. At a minimum, match the washer to the material grade of the bolt and nut. In addition the washer's inside diameter should be just large enough to fit around the bolt. Too large an inside diameter causes more damage that not using a washer. ArcelorMittal Tubarão uses flat washer, avoid using split-ring or helical spring lock washers.(4)

3.6 Application of Specific Torque Requirement

Every application has a specific torque requirement. Too little torque doesn't provide enough mechanical stiffness and permits the nut to loosen further as the machine operates. Too much torque stretches the bolt witch reduces tensile strength and leads to premature failure. The resultant looseness also damages the machine. Mechanical looseness causes excessive movement within the machine or misalignment between machine-train components. Regardless of where it occurs, looseness accelerates wear and reduces operating life.(5)

3.7 Use the Hammer to Fasten Bolted Joint Is Not Permitted

There are three accepted ways of tightening a bolt, stud or fastener: Torque, Tension or Heat. The use of torque is the most widespread throughout industry. Torque can be achieved through manual means, such as flogging, controlled manual means, such as torque multipliers or by use of hydraulically power wrenches using air or electric (4). But unfortunately too many plants don't use, or even have one. Instead, technicians use the biggest cheater bar or the strongest millwright to lock faster in place. This simply doesn't work. Because this, AM Tubarão eliminates the use of hammer to fasten bolted joint.(5)

4 CONCLUSIONS

ArcelorMittal Tubarão follows proper universal bolting practices. The costs generated by poor practices can be substantial. Proper fastening procedures require that the proper fasteners be used in each application, that they are properly assembled and that proper torque is applied. Most operation and maintenance manuals include information on proper fastener selection, assembly and installation.
This work represents all the effort developed by ArcelorMittal Tubarão to eliminate the influence of the bolted joint as a basic cause of equipment failure, contributing to its **availability** and the excellence of maintenance in the company.(5)

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ANNEX A – BOLT TIGHTENING TABLE

MOMENTOS DE APERTO MÁXIMO

Tabela de momentos de aperto para parafusos
Norma
DIN 912, 911, 931, 7984, 7980 e 267
MANNESMANN / DEC, folha n• 9.13

Os valores contidos nesta tabela não podem ser ultrapassados, servindo apenas como referência. Não se aplicam a estruturas tensionadas, devendo nestes casos ser consultados os valores de projetos ou calculados com aprovação da Divisão de Engenharia Mecânica.

MOMENTOS DE APERTO PARA PARAFUSOS COM ROSCA MÉTRICA

PARAFUSO		CLASSES DE RESITÊNCIA DO PARAFUSO											
		4.6		5.6		6.9		8.8		10.9		12.9	
		N m	kg m	N m	kg m	N m	kg m	N m	kg m	N m	kg m	N m	kg m
M8	a	7,40	0,75	9,10	0,93	16,50	1,68	19,50	1,99	27,50	2,80	33,00	3,16
	b	8,50	0,87	10,60	1,08	19,10	1,95	22,60	2,30	32,00	3,26	38,20	3,90
	c	9,10	0,93	11,40	1,16	20,50	2,09	24,30	2,48	34,10	3,48	41,00	4,18
M10	a	14,70	1,50	18,30	1,87	32,90	3,35	39,20	4,00	55,20	5,63	66,20	6,75
	b	16,90	1,72	21,00	2,14	38,00	3,88	45,10	4,60	63,40	6,47	76,10	7,76
	c	18,20	1,86	22,80	2,32	41,20	4,20	48,70	4,97	68,60	7,00	82,20	8,18
M12	a	25,70	2,62	32,30	3,29	58,20	5,93	68,60	7,00	96,10	9,80	116,00	11,80
	b	29,60	3,02	37,10	3,78	66,70	6,80	78,50	8,00	111,00	11,30	124,00	13,60
	c	31,40	3,20	39,20	4,00	70,80	7,22	83,40	8,50	118,00	12,00	141,00	14,40
M14	a	40,20	4,10	50,60	5,16	91,20	9,30	108,00	11,02	152,00	15,50	182,00	18,60
	b	46,10	4,70	57,90	5,90	105,00	10,70	124,00	12,60	174,00	17,70	209,00	21,30
	c	51,00	5,20	63,70	6,50	114,00	11,60	135,00	13,80	189,00	19,30	228,00	23,20
M16	a	61,30	6,25	76,50	7,80	138,00	14,10	164,00	16,70	229,00	23,40	277,00	28,20
	b	71,60	7,10	89,20	9,10	162,00	16,80	191,00	19,50	270,00	27,50	324,00	33,00
	c	77,50	7,90	97,10	9,90	175,00	17,80	207,00	21,10	290,00	29,60	349,00	35,60
M18	a	84,90	5,66	106,00	10,80	191,00	19,50	227,00	23,10	319,00	32,50	382,00	39,00
	b	97,10	9,90	122,00	12,40	219,00	22,30	259,00	26,40	365,00	37,20	436,00	44,50
	c	107,00	10,90	134,00	13,65	240,00	24,50	285,00	29,10	399,00	40,70	481,00	49,00
M20	a	122,00	12,40	152,00	15,50	275,00	28,00	326,00	33,20	457,00	46,60	549,00	56,00
	b	137,00	14,00	172,00	17,50	309,00	31,50	367,00	37,40	515,00	52,50	618,00	63,00
	c	149,00	15,20	186,00	19,00	335,00	34,20	399,00	40,70	560,00	57,10	672,00	68,50
M22	a	163,00	16,60	204,00	20,80	368,00	37,50	436,00	44,50	612,00	62,40	735,00	75,00
	b	187,00	19,10	233,00	23,80	422,00	43,00	500,00	51,00	702,00	71,60	843,00	86,00
	c	201,00	20,50	252,00	25,70	454,00	46,30	537,00	54,80	755,00	77,00	906,00	92,40
M24	a	207,00	21,10	259,00	26,40	466,00	47,50	549,00	56,00	777,00	79,20	932,00	95,00
	b	239,00	24,40	299,00	30,50	539,00	55,00	637,00	65,00	897,00	91,50	1080,00	110,00
	c	255,00	26,00	319,00	32,50	574,00	58,50	682,00	69,50	961,00	98,00	1150,00	117,00
M27	a	306,00	31,20	381,00	38,90	686,00	70,00	814,00	83,00	1150,00	117,00	1330,00	140,00
	b	353,00	36,00	441,00	45,00	794,00	81,00	941,00	96,00	1330,00	136,00	1600,00	163,00
	c	382,00	39,00	481,00	49,00	863,00	88,00	1020,00	104,00	1430,00	146,00	1740,00	177,00
M30	a	412,00	42,00	510,00	52,00	932,00	95,00	1100,00	112,00	1540,00	157,00	1850,00	189,00
	b	481,00	49,00	598,00	61,00	1080,00	110,00	1270,00	130,00	1790,00	183,00	2160,00	220,00
	c	510,00	52,00	637,00	65,00	1160,00	118,00	1370,00	140,00	1820,00	196,00	2310,00	236,00
M33	a	559,00	57,00	696,00	71,00	1270,00	129,00	1500,00	153,00	2110,00	215,00	2530,00	258,00
	b	657,00	67,00	873,00	84,00	1480,00	151,00	1760,00	179,00	2460,00	251,00	2950,00	301,00
	c	696,00	71,00	894,00	89,00	1570,00	160,00	1860,00	190,00	2610,00	266,00	3140,00	320,00
M36	a	716,00	73,00	902,00	92,00	1620,00	165,00	1920,00	196,00	2700,00	275,00	3240,00	330,00
	b	843,00	86,00	1050,00	107,00	1890,00	193,00	2260,00	229,00	3160,00	322,00	3790,00	386,00
	c	902,00	92,00	1120,00	114,00	2010,00	206,00	2400,00	245,00	3370,00	344,00	4050,00	413,00
M39	a	932,00	95,00	1170,00	119,00	2110,00	215,00	2490,00	254,00	3510,00	358,00	4210,00	429,00
	b	1100,00	112,00	1370,00	140,00	2470,00	252,00	2930,00	299,00	4100,00	418,00	4930,00	503,00
	c	1180,00	120,00	1480,00	151,00	2660,00	271,00	3160,00	322,00	4430,00	452,00	5320,00	542,00
M42	a	1150,00	117,00	1440,00	147,00	2590,00	264,00	3070,00	313,00	4310,00	440,00	5180,00	528,00
	b	1350,00	138,00	1690,00	172,00	3040,00	310,00	3610,00	368,00	5060,00	516,00	6080,00	620,00
	c	1440,00	147,00	1800,00	184,00	3250,00	331,00	3850,00	393,00	5420,00	553,00	6500,00	663,00
M45	a	1440,00	147,00	1800,00	184,00	3250,00	331,00	3840,00	392,00	5410,00	552,00	6490,00	662,00
	b	1670,00	170,00	2090,00	213,00	3760,00	382,00	4450,00	454,00	6250,00	637,00	7510,00	766,00
	c	1800,00	184,00	2260,00	230,00	4050,00	413,00	4810,00	490,00	6760,00	689,00	8100,00	826,00

Código de resistência ao atrito μ total

a) Fundidos, estampados;

b) Usinados;

c) Usinado de precisão

COMPANHIA SIDERÚRGICA DE TUBARÃO

DEPARTAMENTO DE MANUTENÇÃO MECÂNICA

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